SEDIMENT TRANSPORT BY STREAMS IN THE UPPER COLUMBIA RIVER BASIN, WASHINGTON MAY 1969 - JUNE 1971

U.S. GEOLOGICAL SURVEY

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A reconnaissance of sediment transport by streams in the upper Columbia River basin of eastern Washington disclosed that (1) in the mountainous areas snowmelt transports most of the sediment during April-June and (2) in the lower, semiarid parts of the basin most of the sediment is transported when warm rain falls on extensive accumulations of snow. During the 1970 and 1971 water years the measured suspended-sediment concentrations ranged from less than 1 milligram per liter in many streams to more than 200,000 milligrams per liter in Providence Coulee. The estimated long-term annual suspended-sediment yields range from less than 10 tons per square mile in many basins to more than 500 tons per square mile in Providence Coulee. Man's activities have caused only a slight increase in the magnitude of sediment discharge to the Columbia River. Although cultivation has initiated a large increase in erosion on the Columbia Plateau, the sediment transport by streams has not increased greatly, because there is little surface runoff on the plateau to transport soils to streams.

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For additional information write to:

U.S. Department of the Interior
Geological Survey
Water Resources Division
1305 Tacoma Avenue South
Tacoma, Washington 98402

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SEDIMENT TRANSPORT BY STREAMS IN THE

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ABSTRACT

This report presents the results of a reconnaissance evaluation of the fluvial-sediment transport by streams in the 28,000-square-mile upper Columbia River basin in eastern Washington. The basin ranges in altitude from about 340 to 9,000 feet, and receives annual precipitation ranging from more than 150 inches in the mountains to less than 10 inches at the lower altitudes. A good vegetative cover is sustained in the mountains by the high precipitation, whereas vegetation is sparse in the lower semiarid parts of the basin.

In the mountainous areas snowmelt runoff transports most of the sediment during April through June. In the semiarid parts of the basin, little runoff occurs during most years, and most of the sediment is transported when heavy, warm rains fall on extensive accumulations of snow. During the 1970 and 1971 water years, the measured suspended-sediment concentrations in the upper Columbia River basin ranged from less than 1 milligram per liter in many streams to more than 200,000 milligrams per liter in Providence Coulee. The estimated long-term annual suspended-sediment yields range from less than 10 tons per square mile in many basins to more than 500 tons per square mile in Providence Coulee.

Man's activities have caused only a slight increase in the magnitude of the sediment discharge to the Columbia River. Although cultivation has initiated a large increase in erosion on the Columbia Plateau, and winds there move some of the loosened or easily eroded soils to depressions and runoff channels, sediment transport by streams has not increased greatly. This is because the little surface runoff on the plateau does not transport the soils to streams and to the Columbia River.

INTRODUCTION

Purpose and Scope

This study was made in cooperation with the State of Washington Department of Ecology as part of a program of evaluating the amount of fluvial sediment transported within major river basins of the State, the probable sources of such sediment, and the factors contributing to its erosion and transport.

Suspended-sediment samples for this study were obtained periodically at 50 sites established in May 1969 on the major streams in the study region. The streams at these sites were sampled at regular 6-week intervals and during periods of storm runoff. Samples also were obtained at 111 reconnaissance sites at various intervals--mostly during storms.

The relation of suspended-sediment concentrations to streamflow (water discharge) during the study period was evaluated mostly from data obtained at 59 stream-gaging stations. Water discharges at periodic sediment-sampling sites were measured by standard Geological Survey methods, whereas discharges at reconnaissance sites were estimated from measured cross-section geometry and surface velocities of streamflow.

The reconnaissance nature of this study required the extrapolation and interpolation of sediment data to areas of limited data coverage. The methods used for obtaining and analyzing suspended-sediment samples collected during this study are described in a series of reports by the U.S. Inter-Agency Committee, Subcommittee on Sedimentation (1940-63).

Acknowledgments

Many of the data analyzed for this report were collected by the Spokane subdistrict office of the U.S. Geological Survey. Critical reviews of the manuscript by W. L. Haushild and P. R. Boucher enhanced the quality of the final report.

Description of the Basin

The upper Columbia River basin, as defined for this study (pl. 1 in pocket), includes the 28,000-square-mile area above Pasco in Washington, but excludes the Pend Oreille and Spokane River basins. The basin extends nearly 200 miles north from Pasco to the Canadian border and over 150 miles east from the Cascade Range crest. The landforms of the basin include steep slopes and narrow valleys in the mountains, rolling foothills, and desert plateaus. The crest of the Cascade Range along the western margin of the basin rises to altitudes ranging from less than 4,000 to nearly 9,000 feet. The mountains in the northern part of the basin, in the Okanogan and Sanpoil River drainages, are relatively low; a few ridges rise above 6,000 feet and only small areas are above 5,000 feet. The Columbia Plateau in the southeastern part of the basin is characterized by scablands and coulees and is generally below altitudes of 2,500 feet. Fenneman (1931) describes the physiography of the basin in greater detail.

FACTORS AFFECTING SEDIMENT TRANSPORT

Precipitation

Precipitation is the major factor affecting sediment transport in the upper Columbia River basin. The various characteristics of precipitation--quantity, areal and seasonal distribution, form (whether it occurs as rain or snow), and intensity--all influence the degree to which sediment is eroded and transported.

The average annual precipitation in the upper Columbia River basin ranges from more than 150 inches along the Cascade Range to less than 10 inches in the lower parts of the area near Pasco (pl. 1; U.S. Weather Bureau, 1965). The prevailing, moisture-laden westerly air currents from the Pacific Ocean cause high precipitation near the crest of the Cascade Range. The precipitation diminishes with a decrease in altitude and increase in distance east from the crest of the range. The average annual precipitation at U.S. Weather Service stations decreases from 94 inches at Stampede Pass (3,958 ft above mean sea level) to 21 inches at Cle Elum (altitude 1,920 ft) 20 miles east of the summit, and decreases to 9 inches at Ellensburg (altitude 1,727 ft) 40 miles east of the range crest. Average annual snowfall on the east slope of the Cascade Range ranges from 300 to 400 inches at the higher altitudes to 75 to 100 inches in the foothills. Intense rain and hail, associated with thunderstorms which develop in the mountains, occasionally cause flash floods in the narrower canyons of the semiarid areas. Because most of the precipitation occurs during the winter when the cold weather of the continental interior moves against the mountains, most precipitation occurs as snow, and the subsequent runoff is mostly snowmelt.

In the northern part of the basin--in the eastern part of Okanogan County, and in Ferry, Stevens, and Pend Oreille Counties--the annual precipitation ranges from about 40 to less than 20 inches. The cold continental air traveling southward through Canada occasionally crosses the Okanogan Highlands and Selkirk Mountains and moves through the north-south valleys into the Columbia Basin. This cold air causes heavy snowfall in the northern mountains and a lesser amount in the Columbia Basin. At the higher altitudes, most of the precipitation that falls as snow in the winter generally causes heavy runoff when it melts in May and June.

In the semiarid southeastern part of the study area, precipitation is usually less than 20 inches annually.

Streamflow

Although the seasonal fluctuations of streamflow in the upper Columbia River basin vary widely from year to year, the fluctuations in the mean monthly flow follow a general pattern (fig. 1) of (1) high runoff during April through June, (2) occasional high streamflow from heavy winter rains, and (3) generally low summer streamflows. The runoff from snowmelt usually starts earliest at the lower altitudes--in February in the Nespelem basin and in April in the Okanogan basin. As shown in figure 1 most of the runoff in the Columbia Basin occurs during late spring through early summer, indicating the influence of snowmelt. Snowmelt runoff is usually gradual and thus the stream channels are not normally subjected to high erosive streamflows. Storage of water for irrigation in the Yakima River basin reduces peak flows, with a resulting reduction in erosion and sediment transport in the lower parts of the basin; only infrequently--and in very small areas--do thunderstorms produce high runoff.

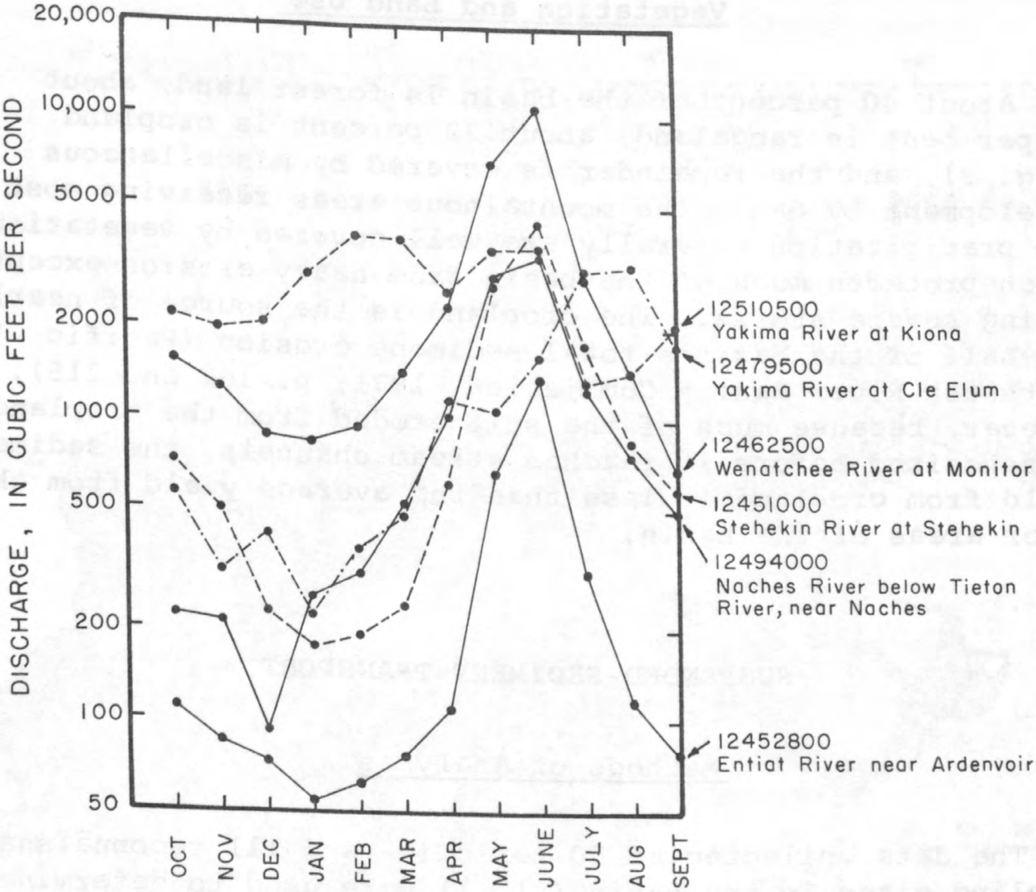

FIGURE 1.--Monthly mean water discharges during 1970 water year at six sites.

Soils

Texture and permeability are two characteristics of soil that strongly influence sediment erosion and transport. Soils in the lowland parts of the upper Columbia River basin are generally finer grained and thicker than soils at the higher altitudes. The coarse-grained soils in mountainous areas generally absorb much of the rainfall, which results in less overland runoff and erosion in the lowlands. Water transports less coarse-grained soil than fine-grained soil, whereas wind transports some of the easily eroded fine-grained soils of the lowland farms to streams.

Vegetation and Land Use

About 40 percent of the basin is forest land, about 35 per cent is rangeland, about 22 percent is cropland (fig. 2), and the remainder is covered by miscellaneous development by man. The mountainous areas receiving most of the precipitation generally are well covered by vegetation, which protects much of the basin from heavy erosion except during severe storms. The cropland is the source of nearly one-half of the basin's total sediment erosion (Pacific Northwest River Basins Commission, 1971, p. 167 and 215). However, because much of the soil eroded from the cropland is deposited before it reaches stream channels, the sediment yield from cropland is less than the average yield from the other areas of the basin.

SUSPENDED-SEDIMENT TRANSPORT

Methods of Analyses

The data collected at 50 periodic- and 111 reconnaissance-sampling sites in the basin (pl. 1) were used to determine several characteristics of suspended-sediment transport by the streams. To establish a relation between suspended-sediment concentration and water discharge, the measured instantaneous suspended-sediment concentrations and concurrent water discharges were plotted on log-log paper and a regression line was drawn using the least-squares method.

The relation of instantaneous suspended-sediment concentration to water discharge was used with a coefficient of 0.0027 (to convert milligrams per liter to tons per day) to form a relation between suspended-sediment discharge and water discharge. These relations (sediment-transport curves) were used as described by Colby (1956); the accuracy of the curves was discussed by Nelson (1971, p. 19).

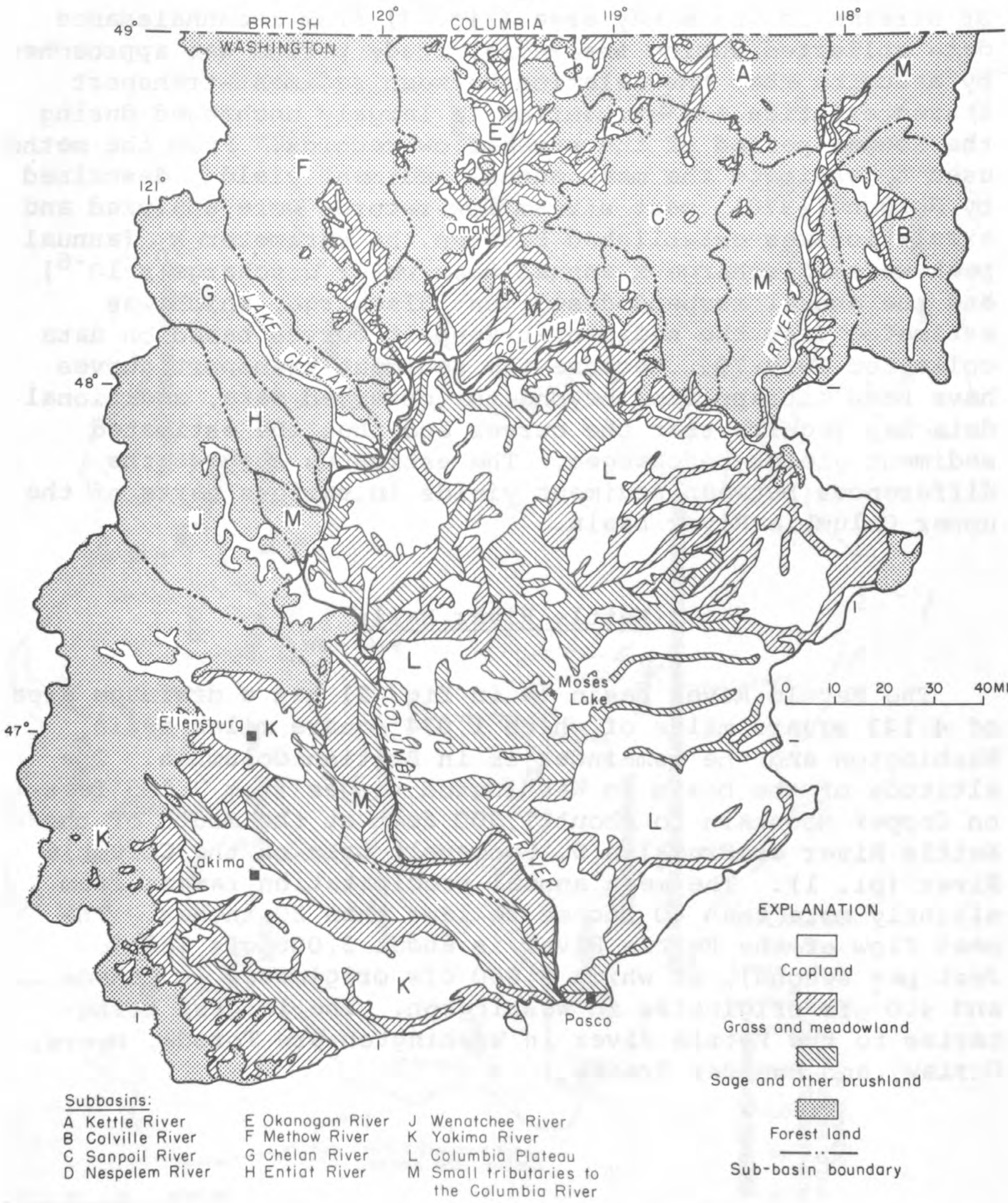

FIGURE 2.--Subbasins studied and generalized land use. (Adapted from Pacific Northwest River Basins Commission, 1971.)

The problem of estimating the mean annual sediment yields of streams in the study area (fig. 3) from reconnaissance data collected during the 2-year study period was approached by assuming that the relation between sediment-transport characteristics and streamflow is largely unchanged during the longer period of the streamflow records. From the method used to estimate the mean annual sediment yields, described by Nelson (1970), past streamflow records were analyzed and a relation was established between the parameter k_n (annual peak water discharge x annual mean water discharge x 10^{-6}) and the annual suspended-sediment discharge, which was estimated from the sediment-transport curves based on data collected 1969-70. Because the sediment-transport curves have been extrapolated beyond the observed data, additional data may require that the curves and thus the estimated sediment yields be changed. The estimates suggest the differences between sediment yields in various parts of the upper Columbia River basin.

Kettle River Basin

The Kettle River basin (A in fig. 2) has a drainage area of 4,143 square miles of which 1,034 square miles is in Washington and the remainder is in British Columbia. The altitude of the basin in Washington ranges from 7,135 feet on Copper Mountain to about 1,300 feet at the mouth of the Kettle River at Franklin D. Roosevelt Lake on the Columbia River (pl. 1). The mean annual precipitation ranges from slightly more than 40 inches to less than 20 inches. The mean flow of the Kettle River is about 3,000 cfs (cubic feet per second), of which 2,600 cfs originates in Canada and 400 cfs originates in Washington. The largest tributaries to the Kettle River in Washington are Toroda, Myers, Curlew, and Boulder Creeks.

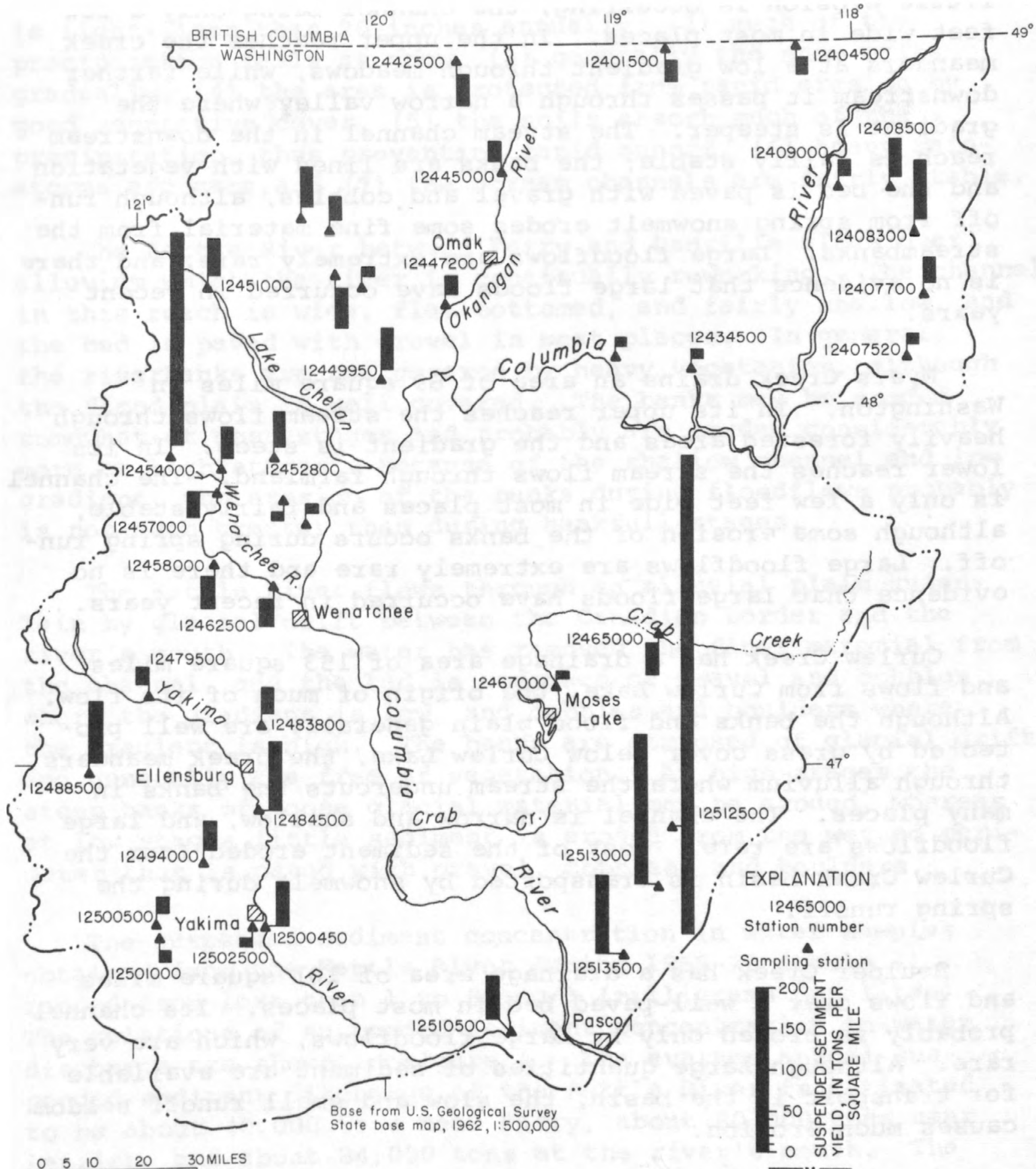

FIGURE 3.--Estimated mean annual suspended-sediment yields of streams, May 1969-June 1971.

Toroda Creek drains an area of 162 square miles. The mountains of the basin are well covered by vegetation and little erosion is occurring, the channel being only a few feet wide in most places. In the upper reaches the creek meanders at a low gradient through meadows, while farther downstream it passes through a narrow valley where the gradient is steeper. The stream channel in the downstream reach is fairly stable; the banks are lined with vegetation and the bed is paved with gravel and cobbles, although runoff from spring snowmelt erodes some fine material from the streambanks. Large floodflows are extremely rare, and there is no evidence that large floods have occurred in recent years.

Myers Creek drains an area of 89 square miles in Washington. In its upper reaches the stream flows through heavily forested areas and the gradient is steep. In its lower reaches the stream flows through farmland. The channel is only a few feet wide in most places and fairly stable, although some erosion of the banks occurs during spring runoff. Large floodflows are extremely rare and there is no evidence that large floods have occurred in recent years.

Curlew Creek has a drainage area of 153 square miles and flows from Curlew Lake, the origin of much of its flow. Although the banks and flood plain generally are well protected by grass cover below Curlew Lake, the creek meanders through alluvium where the stream undercuts the banks in many places. The channel is narrow and shallow, and large floodflows are rare. Most of the sediment eroded from the Curlew Creek basin is transported by snowmelt during the spring runoff.

Boulder Creek has a drainage area of 101 square miles and flows over a well-paved bed in most places. Its channel probably is eroded only by large floodflows, which are very rare. Although large quantities of sediment are available for transport in the basin, the slow and small runoff seldom causes much erosion.

The other tributaries to the Kettle River in Washington are relatively short, small creeks that have sediment-transport characteristics similar to those of Toroda, Curlew, and Boulder Creeks.

The sediment transport by the streams tributary to the Kettle River in Washington is low because (1) precipitation is light--less than 20 inches annually, (2) much of the precipitation falls as snow, (3) generally the snow melts gradually, (4) the area is protected from rapid erosion by good vegetative cover, (5) the soils absorb much of the precipitation, thus preventing rapid runoff, (6) heavy rainstorms are rare,and (7) the stream channels are fairly stable.

The Kettle River between Ferry and Danville flows over alluvium which the river is continually reworking. The channel in this reach is wide, flat bottomed, and fairly shallow, and the bed is paved with gravel in most places. In general, the riverbanks are not covered by heavy vegetation, although the flood plain is well covered. The banks may be eroded somewhat at most stages and probably are eroded considerably more at high stages. Because of the shallow channel and low gradient, the erosion of the banks during floodflows probably is not much greater than during bankfull stages.

The Kettle River flows through an alluvial plain underlain by glacial drift between the Canadian border and the river's mouth. The water has removed the finer material from the channel, and the bed is composed of gravel and cobbles where the gradient is low, and cobbles and boulders where the gradient is high. The banks are composed of glacial drift and generally are free of vegetation. At high stages the steep banks of loose glacial material may be eroded, whereas at low stages little sediment is eroded from the wetted perimeter that is paved with gravel, cobbles, and boulders.

The suspended-sediment concentration in water samples obtained from the Kettle River during 1969-70 (table 1) ranged from less than 1 to 88 mg/l (milligrams per liter). The relations of suspended-sediment concentration to water discharge are shown in figure 4. The average annual suspended-sediment discharge of the Kettle River is estimated to be about 40,000 tons near Ferry, about 80,000 tons near Laurier, and about 84,000 tons at the river's mouth. The average annual discharge of suspended sediment originating in Washington is estimated to be about 20,000 tons.

TABLE 1.--Streamflow and suspended-sediment data for selected stations, upper Columbia River basin

Station number	Station	Drainage area (sq mi)	Length of water-discharge record (years)	Average water discharge for period of record (cfs)	Suspended sediment: Measured concentration (mg/l)		Suspended sediment: Estimated annual yield (tons per sq mi)
					Min.	Max.	
12401500	Kettle River near Ferry	2,220	42	1,481	<1	88	20
12404500	Kettle River near Laurier	3,800	41	2,848	<1	56	20
12407500	Sheep Creek at Springdale	48.2	17	12.0	1	26	--
12407520	Deer Creek near Valley	36.0	11	17.8	4	306	20
12407700	Chewelah Creek at Chewelah	94.1	13	34.8	2	67	20
12408300	Little Pend Oreille River near Colville	132	12	56.9	2	119	40
12408420	Haller Creek near Arden	37.0	11	7.37	1	28	--
12408500	Mill Creek near Colville	83.0	31	47.8	2	129	45
12409000	Colville River at Kettle Falls	1,007	48	299	6	120	15
12434500	Sanpoil River near Keller	890	3	243	1	190	10
12437500	Nespelem River at Nespelem	122	18	39.3	--	--	10
12439300	Tonasket Creek at Oroville	60.1	3	2.12	4	120	--
12439500	Okanogan River at Oroville	3,210	28	656	1	8	--
12442000	Toats Coulee Creek near Loomis	130	12	45.8	<1	235	--
12442500	Similkameen River near Nighthawk	3,550	59	2,260	<1	350	40
12444490	Bonaparte Creek near Wauconda	96.6	--	--	2	76	--
12445000	Okanogan River near Tonasket	7,280	41	2,892	2	156	25
12447200	Okanogan River at Malott	8,100	12	2,904	1	248	25
12447390	Andrews Creek near Mazama	22.1	2	25.5	<1	82	--
12449600	Beaver Creek below South Fork, near Twisp	62.0	10	16.2	<1	601	--
12449950	Methow River near Pateros	1,772	11	1,498	<1	256	50
12451000	Stehekin River at Stehekin	344	49	1,412	1	22	45
12452800	Entiat River near Ardenvoir	203	13	361	<1	188	60
12454000	White River near Plain	150	16	816	1	49	260
12457000	Wenatchee River at Plain	591	60	2,225	1	33	30

12458000	Icicle Creek above Snow Creek, near Leavenworth	193	34	622	<1	16	40
12459000	Wenatchee River at Peshastin	1,000	42	3,069	<1	29	--
12461400	Mission Creek above Sand Creek, near Cashmere	39.8	11	13.0	<1	236	--
12462500	Wenatchee River at Monitor	1,301	8	3,189	1	29	30
12464800	Coal Creek at Mohler	64.7	7	4.12	2	2,320	--
12465000	Crab Creek at Irby	1,042	28	80.4	1	2,010	60
12465400	Wilson Creek below Corbett Draw, near Almira	327	1	26.8	1	4,030	--
12465500	Wilson Creek at Wilson Creek	427	17	12.9	2	2,660	--
12467000	Crab Creek near Moses Lake	2,228	30	--	4	298	10
12470500	Rocky Ford Creek near Ephrata	458	28	80.2	1	4	--
12472600	Crab Creek near Beverly	4,842	12	--	6	204	--
12479500	Yakima River at Cle Elum	495	64	2,008	1	16	15
12480000	Teanaway River below Forks, near Cle Elum	172	3	276	<1	172	--
12483800	Naneum Creek near Ellensburg	69.5	13	55.0	<1	45	10
12484500	Yakima River at Umtanum	1,594	64	--	4	214	50
12488500	American River near Nile	78.9	33	242	<1	108	40
12492500	Tieton River at headworks of Tieton Canal, near Naches	239	64	559	2	18	--
12494000	Naches River below Tieton River, near Naches	941	62	1,714	1	264	30
12500450	Yakima River above Ahtanum Creek, at Union Gap	3,479	5	--	6	148	50
12500500	North Fork Ahtanum Creek near Tampico	68.9	46	68.6	1	58	15
12501000	South Fork Ahtanum Creek at Conrad Ranch, near Tampico	24.8	40	19.2	<1	34	25
12502500	Ahtanum Creek at Union Gap	173	--	--	4	242	20
12510500	Yakima River at Kiona	5,615	46	--	2	286	50
12512500	Providence Coulee at Cunningham	27.8	18	.32	538	234,000	600
12513000	Esquatzel Coulee at Connell	234	18	1.45	850	45,100	200
12513500	Esquatzel Coulee at Eltopia	551	18	.88	1,460	5,170	100

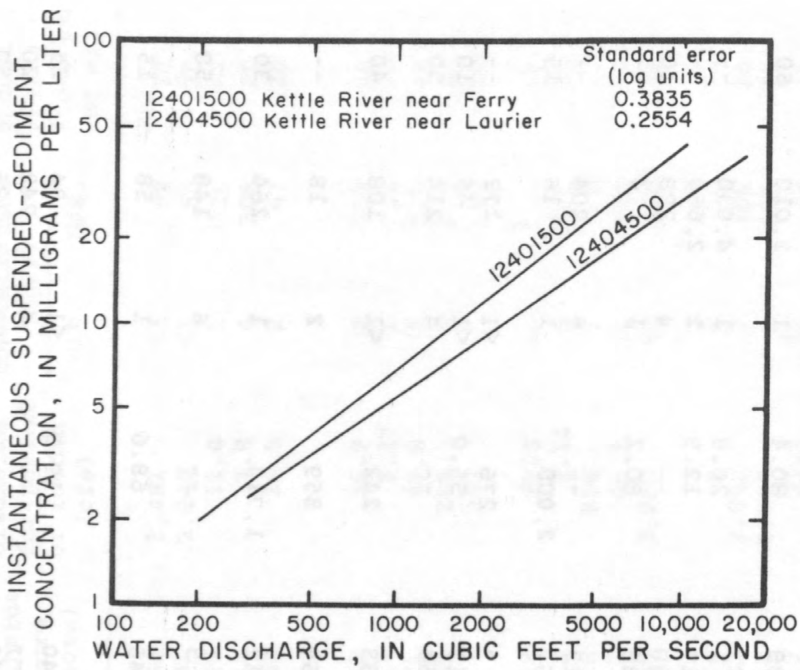

FIGURE 4.--Relation of suspended-sediment concentration to water discharge at two sites in the Kettle River basin.

The average annual suspended-sediment yields of the entire Kettle River basin is estimated to be 20 tons per square mile. The suspended-sediment concentrations measured at periodic- and reconnaissance-sampling sites in the Kettle River basin during the study period are listed in tables 2 and 3, respectively.

TABLE 2.--Suspended-sediment concentrations at two periodic-sampling sites in the Kettle River basin. Sites are as shown on plate 1 and listed in table 1

Date	Time (24 hr)	Water temper- ature (°C)	Dis- charge (cfs)	Suspended- sediment concentra- tion (mg/l)
12401500. Kettle River near Ferry Lat 48°58'53", long 118°45'55"				
5-20-69	1330	9.5	9,230	71
7-24	1640	21.5	582	4
8-28	1150	14.0	141	<1
10- 1	1515	10	490	4
11- 5	1545	6.5	420	4
12-11	1550	.5	342	1
2- 5-70	1135	1.5	209	1
3- 5	1145	2.0	242	<1
4- 1	1035	10.0	349	3
6-25	1520	20	1,530	2
8-13	1445	22	158	5
4-22-71	1130	11	1,740	47
5-20	1430	7.5	6,590	20
6- 3	1310	8.5	10,000	88
6-16	1230	9.5	6,350	24
6-16	1530	11	6,430	10
6-30	1215	12.0	4,030	11
12404500. Kettle River near Laurier Lat 48°59'04", long 118°12'55"				
5-20-69	1615	10.5	16,200	45
7-24	1155	22.0	1,320	6
9- 3	0950	14.5	294	<1
10- 1	1300	8	572	6
11- 5	1125	7	729	2
12-11	1045	1.0	720	1
1-27-70	--	1.0	537	1
3- 5	1640	3.5	457	1
4- 1	1545	9.0	928	3
6-25	1200	22	3,020	1
8-13	1045	22	313	4
4-23-71	1615	9.0	4,720	56
5-20	1000	7.5	12,000	30
6- 3	1500	10.0	15,400	42
6-16	1100	11.5	11,300	22
6-16	1420	11.5	11,100	26
6-30	1355	13.5	7,240	12

TABLE 3.--Suspended-sediment concentrations at three reconnaissance-sampling sites in the Kettle River basin. Sites are shown on plate 1 and are located only by latitude and longitude. Water discharge was estimated from measured cross-section geometry and surface velocity

Date	Time (24 hr)	Water temperature (°C)	Discharge (cfs)	Suspended-sediment concentration (mg/l)
Kettle River at Danville Lat 48°59'28", long 118°30'14"				
6- 3-71	1350	5.0	--	51
6-16	1315	9.5	--	44
6-30	1245	13.5	--	63
Boulder Creek near Orient Lat 48°50'08", long 118°10'59"				
6- 3-71	1545	10.0	80	32
Kettle River near Barstow Lat 48°47'06", long 118°07'25"				
5-20-69	1615	10.5	--	45
6- 3-71	1610	10.5	--	38
6-16	1510	11.0	--	30
6-30	1445	13.5	--	16

Colville River Basin

The Colville River basin (B in fig. 2) covers an area of 1,020 square miles in the northeastern part of the upper Columbia River basin (pl. 1). Altitudes range from 6,855 feet on Calispell Peak to about 1,290 feet at Franklin D. Roosevelt Lake (Columbia River) at the mouth of the Colville River. The average annual precipitation in the basin ranges from less than 15 inches near Arden to about 40 inches near Calispell Peak (pl. 1; U.S. Weather Bureau, 1965). The precipitation is seasonal, with about two-thirds of the annual total occurring during October-March.

The basin consists largely of rough, stony, and mountainous areas that are evenly covered by vegetation. At the higher altitudes the soils are thin, whereas in the bottom of the main Colville River valley loam soils are underlain by alluvium. The soils are sometimes severely eroded during occasional intense rainstorms. Rapid snowmelt in the spring usually causes some channel changes in the lower valleys where the streams flow across glacial and alluvial deposits. In the lower reaches of Mill Creek and Little Pend Oreille River the streambanks are eroded considerably during periods of rapid runoff. Some reworking of the glacial deposits is occurring in the Colville River channel where the gradient is high, but the tributaries at the lower altitudes with lower gradients transport little sediment.

Land use in the Colville River basin (fig. 2) causes only small changes in the sediment discharge. Cultivation of lands used for hay, pasture, and small grain crops exposes the bare soil for only short periods. Some temporary changes in the sediment discharge from the mountainous areas probably occur as a result of timber harvesting.

The sediment discharge from the Colville River basin is small because of (1) the small amount of precipitation, which occurs mostly as snow; (2) small peak streamflows; (3) small tributaries; and (4) well-vegetated drainage areas.

In the Colville River basin suspended-sediment samples were collected periodically at seven gaging stations (table 4) and on a reconnaissance basis at eight sites (table 5). The relations of suspended-sediment concentration to water discharge are shown in figure 5. Suspended-sediment concentrations ranged from 1 mg/l at many sites to 308 mg/l in the

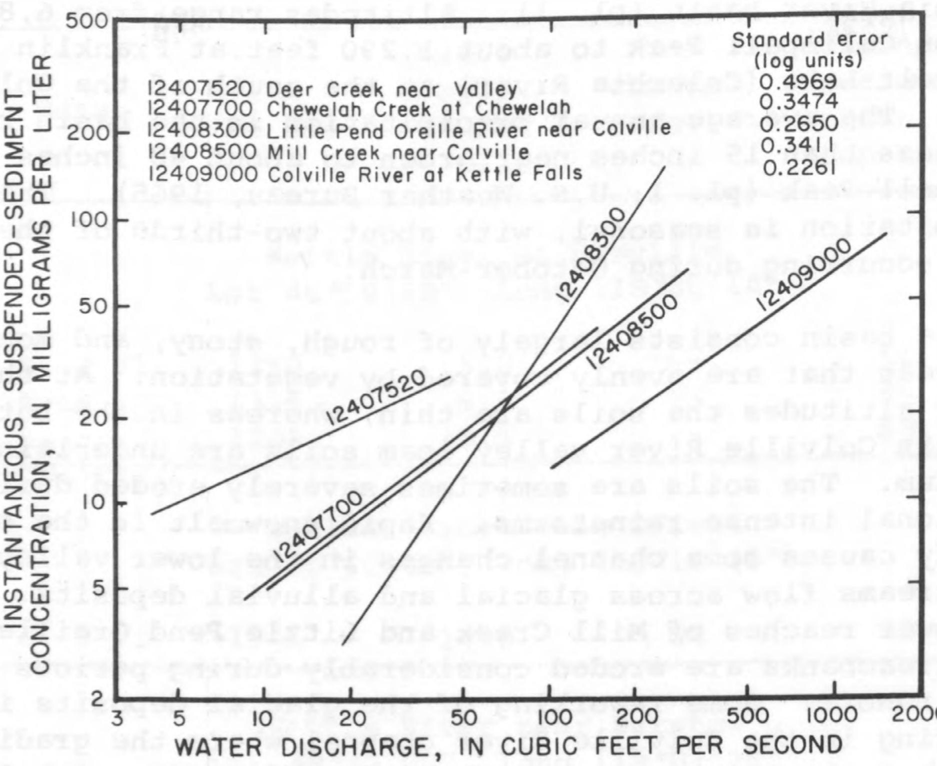

FIGURE 5.--Relation of suspended-sediment concentration to water discharge at five sites in the Colville River basin.

Little Pend Oreille River near its mouth. Because Little Pend Oreille River and Mill Creek are longer and have greater runoff, they produce greater sediment yields than do the other small streams. The average annual suspended-sediment yields per square mile of parts of the Colville River basin are estimated to be as follows: (1) Colville River, 15 tons; (2) Little Pend Oreille River, 40 tons; (3) Chewelah Creek, 20 tons; (4) Deer Creek, 20 tons; and (5) Mill Creek, 45 tons. The yields of the basins of Haller and Sheep Creeks were not estimated.

TABLE 4.--Suspended-sediment concentrations at seven periodic-sampling sites in the Colville River basin. Sites are as shown on plate 1 and listed in table 1

12407500. Sheep Creek at Springdale
Lat 48°03'28", long 117°45'04"

Date	Time (24 hr)	Water temperature (°C)	Discharge (cfs)	Suspended-sediment concentration (mg/l)
7-22-69	1500	18.0	7.16	11
8-26	1630	14.0	7.98	12
9-30	1455	11	11.9	8
11- 3	1605	6.0	18.6	4
12- 9	1500	3	10.5	3
1- 6-70	1410	0	8.47	9
2- 3	1305	4.0	9.87	6
3- 9	1140	5.0	12.1	4
3-31	1010	5.0	28.6	17
4- 3	1500	8.5	54.7	26
5-12	1310	12	10.9	3
6-23	1145	17	7.76	7
8-10	1545	15	6.75	4
4-20-71	0900	8.5	48	20
4-29	1330	9.0	16	11
6-18	1120	14	6	1

12407520. Deer Creek near Valley
Lat 48°07'06", long 117°47'52"

Date	Time (24 hr)	Water temperature (°C)	Discharge (cfs)	Suspended-sediment concentration (mg/l)
7-22-69	1615	18.0	10.6	10
8-27	1105	6.0	3.83	4
9-30	1320	10.5	6.39	14
11- 7	1420	5.5	8.33	306
12-12	1610	3.0	8.21	12
1-14-70	1540	3.5	9.48	18
2- 3	1405	3.0	9.63	4
3- 6	1555	3.0	13.6	16
3-31	1025	5.5	45.3	62
5-12	1415	11	30.3	20
6-23	1345	19	9.75	20
8-11	0955	13	5.42	11
4-20-71	1045	8.5	100	61
6-18	1115	13	30	5

12407700. Chewelah Creek at Chewelah
Lat 48°17'01", long 117°42'50"

Date	Time (24 hr)	Water temperature (°C)	Discharge (cfs)	Suspended-sediment concentration (mg/l)
7-23-69	1000	14.0	18.5	8
8-27	1405	16.5	7.74	3
9-30	1015	14	24.8	26
11- 4	1140	6.5	17.0	3
12-10	0920	3.5	16.0	3
1- 7-70	0805	1.0	8.54	4
2- 4	1120	3.0	16.3	2
3- 4	1055	2.0	11.8	12
3-31	1345	8.0	44.8	20
4-23	1130	7.0	211	14
5-13	1010	8.5	61.6	28
6-23	1530	19	24.1	12
8-11	1150	18	6.36	8
4-20-71	1340	10.5	75	53
4-29	1520	9.0	101	67
6-17	1455	15	38	22

12408300. Little Pend Oreille River near Colville
Lat 48°27'58", long 117°44'53"

Date	Time (24 hr)	Water temperature (°C)	Discharge (cfs)	Suspended-sediment concentration (mg/l)
7-23-69	1335	19.5	34.1	10
9- 4	1035	9.5	19.7	2
10- 2	1015	8	35.6	8
11- 6	1000	5.5	39.3	10
12-10	1440	.5	21.2	2
1- 8-70	1000	0	18.2	4
2- 6	1010	1.5	24.1	2
3- 6	0940	2.0	26.8	10
4- 2	0855	4.0	58.7	54
5-14	1005	9.0	173	119
8-12	1000	16	17.1	4
4-20-71	1555	9.5	119	64
5- 6	1400	10	242	61
6-17	1710	15.5	56	10

12408420. Haller Creek near Arden
Lat 48°28'02", long 117°54'24"

Date	Time (24 hr)	Water temperature (°C)	Discharge (cfs)	Suspended-sediment concentration (mg/l)
9- 2-69	1620	14.5	1.46	5
10- 2	1520	10.0	3.65	2
11- 7	1105	5.5	3.92	1
12-12	1435	4.5	3.76	6
1- 8-70	1455	.5	2.97	14
2- 6	1440	2.0	3.95	2
3- 4	1205	.5	4.60	28
4- 3	0935	4.5	12.4	24
5-15	0945	9.0	10.5	24
6-26	1430	19	3.09	8
8-12	1100	16	1.15	14

12408500. Mill Creek near Colville
Lat 48°34'44", long 117°51'56"

Date	Time (24 hr)	Water temperature (°C)	Discharge (cfs)	Suspended-sediment concentration (mg/l)
7-23-69	1550	18.5	30.7	7
9- 4	1350	12.0	12.7	4
10- 2	1220	9	24.7	6
11- 6	1245	8.5	20.2	2
12-12	1330	5.5	16.9	40
1- 8-70	1215	1.5	11.3	7
2- 6	1225	4.5	14.4	8
3- 4	1425	3.5	12.6	10
4- 2	1145	6.0	52.8	41
4-23	0900	5.0	--	42
5-14	1205	9.0	115	23
6-24	1220	18	33.1	10
8-11	1500	19	9.49	6
4-23-71	1320	6.5	181	45
4-29	1630	8.0	284	129
5- 6	1600	10	314	124
5-12	1335	14	246	42
5-19	1600	8.5	161	30
6-15	1625	15	80	6

12409000. Colville River at Kettle Falls
Lat 48°35'40", long 118°03'53"

Date	Time (24 hr)	Water temperature (°C)	Discharge (cfs)	Suspended-sediment concentration (mg/l)
5-21-69	0820	11.0	1,120	38
7-25	0925	19.0	228	20
10- 1	1015	9.5	188	16
11- 6	1610	8	231	12
12-12	1030	1.5	172	16
1- 9-70	1010	0	144	6
2- 4	1525	.5	244	13
3- 6	1325	3.0	269	30
4- 2	1510	7.0	495	68
5-13	1605	10	658	52
8-12	1510	23	59.5	28
1-27-71	1615	5.0	316	30
3-19	1735	5.0	451	48
3-30	1150	9.5	520	90
4-14	1300	10.5	1,190	120
4-23	1000	9.0	1,040	72
4-29	1400	10.0	1,480	96
5- 5	1400	13.5	1,320	52
5-12	1030	17	998	50
5-19	1405	12	730	46
6-15	1400	16	454	42

TABLE 5.--Suspended-sediment concentrations at eight reconnaissance-sampling sites in the Colville River basin. Sites are shown on plate 1 and are located only by latitude and longitude. Water discharge was estimated from measured cross-section geometry and surface velocity

Date	Time (24 hr)	Water temper- ature (°C)	Dis- charge (cfs)	Suspended- sediment concentra- tion (mg/l)
Colville River at Valley Lat 48°10'33", long 117°43'43"				
4-23-70	1245	9.0	--	34
South Fork Chewelah Creek Lat 48°17'28", long 117°42'50"				
4-23-70	1210	7.0	--	27
North Fork Chewelah Creek Lat 48°17'26", long 117°43'00"				
4-23-70	1320	8.0	--	20
Little Pend Oreille River near mouth Lat 48°27'40", long 117°52'33"				
4-23-70	1500	8.0	--	308
4-29-71	1545	9.0	200	81
Colville River at Arden Lat 48°27'36", long 117°53'12"				
4-23-70	1410	9.5	--	55
Mill Creek Lat 48°36'47", long 117°46'46"				
4-23-70	0925	5.0	--	16
Mill Creek Lat 48°34'23", long 117°56'39"				
4-23-70	1000	6.5	--	64
4-29-71	1430	9.5	--	149
Colville River Lat 48°35'19", long 117°59'28"				
4-29-71	1425	9.5	--	129

Sanpoil River Basin

The Sanpoil River basin (C in fig. 2) covers an area of 901 square miles and flows south through a narrow valley flanked by mountains with peaks 4,000 to 7,000 feet above sea level. The altitudes in the basin range from 7,135 feet on Copper Butte to about 1,290 feet at Franklin D. Roosevelt Lake. The annual precipitation in the basin ranges from less than 15 inches to over 25 inches. The West Fork of the Sanpoil River is the only large tributary; the other tributaries are short and have steep gradients.

The sediment yield from the Sanpoil River basin is low because of (1) good vegetative cover, (2) soils that are not easily transported, and (3) light precipitation and runoff. A considerable part of the large spring runoff of the Sanpoil River flows over a well-grassed flood plain. The tributaries generally have high gradients, as does the lower reach of the Sanpoil River. The spring runoff in the basin streams is usually clear, indicating that much of the sediment being transported is of sand size or larger. An exception was observed in the North and South Nanamkin Creeks and Anderson Creek, where considerable quantities of fine sediment are transported. The tributaries generally have gravel and cobble beds. High flows undercut the banks in many places, although well-vegetated banks prevent extreme erosion except during very large floods. Flash floods (from thunderstorms) are infrequent. Logging, road building, and recreational developments probably have only minor effect upon the sediment transport by streams in the basin.

Suspended-sediment samples obtained periodically from the Sanpoil River near Keller showed that suspended-sediment concentrations ranged from less than 1 to 190 mg/l. During spring runoff, Anderson and Bridge Creeks and the West Fork Sanpoil River have higher suspended-sediment concentrations than does the Sanpoil River near Keller. Although these streams supplied only an estimated 40 percent of the basin's streamflow during observed runoff, they supplied an estimated 70 percent of the suspended sediment discharged by the Sanpoil River near Keller. The highest suspended-sediment concentrations measured in the basin were 564 mg/l in North Nanamkin Creek, 563 mg/l in Anderson Creek, 290 mg/l in the West Fork Sanpoil River, and 287 mg/l in Bridge Creek.

Only a short streamflow record is available for the Sanpoil River near Keller and, therefore, the estimate of long-term sediment yield may be in considerable error. The annual suspended-sediment yields estimated for the basin ranged from 15 tons per square mile in 1953 to 6 tons per square mile in 1954 and 1955, whereas the long-term annual yield is estimated to be about 10 tons per square mile. The suspended-sediment concentrations measured at periodic- and reconnaissance-sampling sites in the Sanpoil River basin during the study period are listed in tables 6 and 7, respectively, and the relation of suspended-sediment concentration to water discharge is shown in figure 7.

TABLE 6.--Suspended-sediment concentrations at a periodic-sampling site in the Sanpoil River basin. Site is shown on plate 1 and listed in table 1

Date	Time (24 hr)	Water temperature (°C)	Discharge (cfs)	Suspended-sediment concentration (mg/l)
12434500. Sanpoil River near Keller Lat 48°06'30", long 118°41'50"				
5-21-69	1515	--	1,150	40
7-14	1105	16.0	130	4
8-25	1030	16.0	31	2
10- 6	1055	8.5	42	1
11-17	1025	2.0	51	5
2-24-70	1030	3.0	160	5
3-30	1220	6.5	470	29
5-11	1040	--	612	22
6-15	1015	14.0	160	5
7-20	1530	24.5	25	2
8-31	1240	19.0	--	4
10-12	1025	6.5	--	4
11-30	1045	0	130	4
2-22-71	1050	3.5	151	2
4-16	1155	5.5	1,850	64
4-27	0930	8.0	2,550	147
4-27	1525	10.0	2,580	190
4-28	1050	7.0	2,500	190
4-29	1110	7.0	2,340	90
5-12	1450	--	1,620	52
6- 3	1020	10.5	714	24
6- 7	1055	13.5	660	22
6-17	1045	14.0	365	33
6-30	0850	12.0	258	8

TABLE 7.--Suspended-sediment concentrations at 12 reconnaissance-sampling sites in the Sanpoil River basin. Sites are shown on plate 1 and are located only by latitude and longitude. Water discharge was estimated from measured cross-section geometry and surface velocity

Date	Time (24 hr)	Water temper-ature (°C)	Dis-charge (cfs)	Suspended-sediment concentra-tion (mg/l)
Sanpoil River Lat 48°39'08", long 118°42'04"				
4-27-71	1325	8.0	70	47
Granite Creek Lat 48°38'04", long 118°43'13"				
4-27-71	1340	8.0	150	114
Golden Harvest Creek Lat 48°34'20", long 118°44'34"				
4-27-71	1355	5.0	30	42
Scatter Creek Lat 48°42'56", long 118°44'55"				
4-27-71	1410	5.5	100	72
Sanpoil River Lat 48°29'00", long 118°44'11"				
4-27-71	1420	8.5	--	56
Thirteenmile Creek Lat 48°28'50", long 118°43'34"				
4-27-71	1225	5.5	60	22
Gold Creek Lat 48°23'50", long 118°52'20"				
5-12-71	1330	11.2	200	14
West Fork Sanpoil River Lat 48°27'33", long 118°44'57"				
4-27-71	1210	6.0	--	290
5-12	1355	12.2	500	160
Anderson Creek Lat 48°22'48", long 118°44'47"				
4-27-71	1445	7.0	80	563
North Nanamkin Creek Lat 48°18'39", long 118°44'13"				
4-27-71	1450	8.5	100	564
South Nanamkin Creek Lat 48°18'05", long 118°44'03"				
4-27-71	1500	8.5	70	114
Bridge Creek Lat 48°13'29", long 118°41'23"				
4-27-71	1130	6.5	100	287

Nespelem River Basin

The Nespelem River basin (D in fig. 2) covers an area of 224 square miles adjacent to and north of the Columbia River (pl. 1). The basin ranges in altitude from 6,774 feet on Moses Mountain to 905 feet at Rufus Woods Lake (Columbia River) at the mouth of the Nespelem River. Most of the streamflow originates at altitudes of 2,000 feet or higher. The main stem Nespelem River valley extends for about 14 miles, from north of the Colville Indian Agency to the confluence of the Nespelem River with North Star and Stepstone Creeks.

Most of the Nespelem River basin receives less than 20 inches of precipitation annually, with the higher part of the basin--in the vicinity of Moses Mountain--receiving slightly more than 30 inches annually (pl. 1). Much of the runoff is from snowmelt during April through June. The precipitation occurring as rainfall usually is absorbed by the dry, coarse soils. These conditions cause a small runoff--the average discharge at the gaging station at Nespelem (drainage area of 122 sq mi) during 1911-29 was 39.3 cfs, equivalent to a yield of 0.32 cfs per square mile.

The Nespelem River between its confluence with North Star and Stepstone Creeks and Colville Indian Agency generally has a low gradient and meanders considerably. Much of the sediment from steeper tributaries is deposited in this reach of the Nespelem River during most years and eroded from the channel during periods of high streamflow. A mile west of Colville Indian Agency the Nespelem River flows in a narrow bedrock canyon where little sediment is available for transport.

The suspended-sediment concentration ranges from 18 mg/l in the Nespelem River at Nespelem to 148 mg/l in the river at its confluence with North Star and Stepstone Creeks.

The Little Nespelem River, the largest tributary, transports little sediment as its basin has a fair cover of grass and very little runoff. The small size of the stream channel indicates little erosion or runoff in this basin.

The long-term sediment yield from the Nespelem River basin is small, probably less than 10 tons per square mile. However, logging in some areas bares soils that could be easily eroded during severe thunderstorms, and the long-term sediment yield of the basin could be increased considerably by one severe rainstorm. The suspended-sediment concentrations observed at reconnaissance-sampling sites in the basin during the study period are listed in table 8.

TABLE 8.--Suspended-sediment concentrations at four reconnaissance-sampling sites in the Nespelem River basin. Sites are shown on plate 1 and are located only by latitude and longitude. Water discharge was estimated from measured cross-section geometry and surface velocity

Date	Time (24 hr)	Water temperature (°C)	Discharge (cfs)	Suspended-sediment concentration (mg/l)
Nespelem River Lat 48°14'55", long 118°58'27"				
4-28-71	1330	8.0	400	148
5-12	1215	12.6	250	112
Mill Creek Lat 48°12'34", long 118°59'05"				
4-28-71	1315	10.0	80	12
5-12	1150	15.8	20	6
Nespelem River at Nespelem Lat 48°09'54", long 118°58'45"				
6- 4-71	1120	12.0	100	18
Nespelem River at Colville Agency Lat 48°08'04", long 118°59'06"				
4-28-71	1350	10.0	600	19
5-12	1135	16.6	300	46

Okanogan River Basin

The Okanogan River flows south from British Columbia near Oroville to the Columbia River near Brewster (pl. 1). About 95 percent of the water in the Okanogan River and its larger tributary, the Similkameen River, originates in British Columbia. The altitude of the Okanogan River basin (E in fig. 2) in Washington ranges from 8,334 feet at Windy Peak in the Toats Coulee Creek drainage to 780 feet at the mouth of the Okanogan River at the Columbia River. The valley floor of the Okanogan River is bordered by multiple river terraces which extend locally as much as 500 feet above the river. The mountain slopes beyond the terraces rise steeply to altitudes of 5,000 to 8,000 feet.

The annual precipitation in the Okanogan River basin ranges from more than 40 inches to less than 10 inches (pl. 1). Nearly 50 percent of the precipitation falls during October through January. Although July and August generally are very dry months, sufficient rain falls at the higher altitudes to maintain good vegetative cover there. Because much of the precipitation falls as snow, most of the runoff occurs when the snowpack melts in May and June.

The thin soils of the mountainous part of the basin are underlain chiefly by granitic and metamorphic rocks, except in the triangular area between the Columbia and Okanogan Rivers and Omak Lake, which is underlain by basalt of the Columbia River Group. The Okanogan River valley has been greatly modified by the advance and the retreat of glaciers during the Pleistocene Epoch. Large deposits of rock debris reworked by glacial melt water form the broad terraces above the main valley floor whereas alluvium underlies the floors of the main valley and side valleys. The soils of the basin include those formed from (1) volcanic ash and pumice, (2) glacial till and outwash, (3) alluvium, (4) lake sediments, and (5) aeolian silts.

Most of the mountainous part of the Okanogan River basin is forested land (fig. 2), much of which is used for timber harvesting and recreation. The present sediment yield from the forest land is low, although it could increase greatly with an increase in logging (Pacific Northwest River Basins Commission, 1971, p. 187-189).

Little sediment is eroded from the lower parts of the Okanogan River basin because there the precipitation and runoff are low and little land is cultivated for farming.

During 1969-70 suspended-sediment samples were collected periodically at seven gaging stations and on a reconnaissance basis at three sites. Measured suspended-sediment concentrations ranged from less than 1 mg/l at numerous sites to 350 mg/l in the Similkameen River near Nighthawk. The streamflow is nearly clear in all parts of the basin except during spring runoff, generally in May and June, when the streams transport most of the annual sediment discharge. Thunderstorms during summer are fairly common and severe storms occasionally cause rapid runoff and large sediment discharges.

A number of samples obtained in the Okanogan River basin during a period of several days indicate that (1) during low flows the suspended-sediment concentrations are similar throughout the basin, (2) during medium flows the concentrations in the Similkameen River are greater upstream from Enloe Reservoir (near Nighthawk) than downstream from the reservoir (at Oroville), and (3) during high flows the concentrations in the Similkameen River are smaller near Nighthawk than at Oroville and the concentrations in the Okanogan River are greater near Tonasket than at Malott.

With most of the water in the Okanogan River coming from British Columbia--and most of that from the Similkameen River--the inflow from tributaries in Washington contributes little to the total sediment yield of the basin. The Okanogan River at Oroville, upstream from its confluence with the Similkameen River, contributes only 22 percent of the total water discharge of the entire river and had measured suspended-sediment concentrations of less than 10 mg/l during 1969-71. In contrast, measured suspended-sediment concentrations in Toats Coulee Creek, a small tributary in the Okanogan River basin (pl. 1), ranged from less than 1 mg/l during much of the year to 235 mg/l during spring runoff. However, most of the sediment transported by Toats Coulee Creek is deposited in Palmer Lake where, because of the small streamflow in the Toats Coulee Creek-Sinlahekin Creek drainage, there is only a slight effect of sediment deposition on the volume of the lake.

During spring runoff, when the flow of the Similkameen River exceeds a certain stage, some water from the river flows into Palmer Lake and deposits some sediment. When the river stage is again lowered, some of the water in the lake flows back into the Similkameen River and returns to the river part of the previously deposited sediment. The net deposition of sediment in Palmer Lake during this sequence of events is unknown, but probably is small.

Although the rocky, mountainous watershed of the Okanogan River is not subject to severe erosion, summer thunderstorms cause considerable sediment transport from small areas. However, the short duration of the thunderstorms generally results in only small volumes of water that transport the sediment only short distances downstream. Along the terraces above the floor of the downstream reach of the Okanogan River valley, summer thunderstorms can produce rapid runoff there which erodes and transports large quantities of the glacio-fluvial deposits. Occasionally some of these sediments are deposited along the Okanogan River channel where they subsequently are reworked by high streamflows. During the 1948 flood, Tonasket Creek carried a large quantity of sediment to be deposited in the Okanogan River at their confluence

Most of the tributary inflow to the Okanogan River main stem occurs during periods of high streamflow; the tributaries therefore transport very little sediment to the Okanogan River except during an occasional extreme flood.

The annual suspended-sediment discharges at three sites in the Okanogan River basin are estimated to be 140,000 tons in the Similkameen River near Nighthawk and 200,000 tons each in the Okanogan River near Tonasket and at Malott. As very little sediment is transported from Osoyoos Lake by the Okanogan River, these figures indicate that the Similkameen and Okanogan Rivers erode 60,000 tons annually from their channels between Nighthawk and Tonasket. It is also apparent that the erosion and deposition downstream from Tonasket are nearly balanced and that little sediment is transported to the Okanogan River by streams tributary to this reach.

The Similkameen River basin upstream from Nighthawk produces an annual suspended-sediment yield of 40 tons per square mile. Because the water yield in Washington is smaller, the sediment yields from the river in British Columbia would be higher than in Washington. Therefore, most of the annual suspended-sediment yield of the Okanogan River upstream from Tonasket (25 tons per square mile) and upstream from Malott (25 tons per square mile) is from the Similkameen River drainage. The suspended-sediment concentrations measured at periodic- and reconnaissance-sampling sites in the Okanogan River basin during the study period are listed in tables 9 and 10, respectively, and the relations of suspended-sediment concentration to water discharge at three sites in the Okanogan River basin are shown in figure 6.

TABLE 9.--Suspended-sediment concentrations at seven periodic-sampling sites in the Okanogan River basin. Sites are as shown on plate 1 and listed in table 1

Date	Time (24 hr)	Water temper- ature (°C)	Dis- charge (cfs)	Suspended- sediment concentra- tion (mg/l)
12439300. Tonasket Creek at Oroville Lat 48°56'35", long 119°24'45"				
7-15-69	1220	20.0	0.84	4
2-24-70	1625	4.5	1.09	79
3-12	0845	1.5	1.07	48
4- 1	0920	5.5	2.85	79
5-11	1600	.5	4.79	12
5-25	1645	19.0	1.00	10
6- 3	0910	13.0	3.90	36
4-12-71	1755	9.5	--	120
4-15	0920	6.0	--	70
5-14	0845	7.0	--	36
6- 4	1135	15.0	--	16
6-10	0835	11.5	--	13
12439500. Okanogan River at Oroville Lat 48°55'51", long 119°25'09"				
7-15-69	1110	20.5	526	6
8-26	1030	20.0	434	2
10- 7	1145	9.0	635	4
11-18	1410	8.0	383	7
1- 7-70	1200	1.0	494	2
2-25	0945	3.5	230	1
4- 1	1220	8.0	244	3
5-12	0945	11.5	544	2
5-25	--	19.5	836	1
6- 1	--	--	521	5
6-15	1530	19.0	122	1
7-21	0940	23.5	205	6
4- 4-71	1305	8.0	--	8
6- 4	1055	15.5	--	1
6-10	1700	20.0	--	2
6-17	1330	19.5	--	3
12442000. Toats Coulee Creek near Loomis Lat 48°50'01", long 119°41'32"				
7-16-69	1250	13.5	26.6	4
8-27	1305	14.0	6.04	<1
10- 8	1645	8.5	10.8	<1
11-19	1320	1.0	10.2	1
1- 6-70	1105	0	8.04	<1
2-26	1110	.5	8.40	1
3-11	1515	1.5	7.40	<1
3-31	1530	5.0	8.20	1
5-13	1005	4.5	29.4	2
6- 2	1405	5.5	244	8
6- 3-71	0920	6.0	652	235
6-16	0910	6.5	200	5
6-29	1535	10.5	--	3
12442500. Similkameen River near Nighthawk Lat 48°59'05", long 119°37'02"				
5-20-69	0930	9.5	11,900	72
7-14	1910	18.0	1,780	6
8-26	1510	19.0	342	3
10- 8	1415	--	682	2
11-19	1115	3.5	681	1
1- 7-70	1535	.5	272	<1
2-25	1600	4.0	362	1
3-31	1230	8.0	454	2
5-13	1500	10.0	1,970	5
5-20	1310	11.0	--	67
6- 2	1030		8,790	104
6-11	1435	11.5	7,740	65
7-21	1450	19.0	750	1
2-23-71	1110	2.0	1,130	5
4-14	1605	10.5	--	2
5-12	1530	11.5	14,600	350
6- 3	0825	8.5	17,000	106
6- 8	1050	9.0	18,500	88
6-16	0720	10.0	--	76
6-16	0830	9.5	11,200	72
6-29	1610	13.5	7,400	36
12444490. Bonaparte Creek near Wauconda Lat 48°39'26", long 119°12'02"				
7-14-69	1345	14.0	4.44	16
8-25	1655	13.0	1.28	2
10- 6	1410	9.5	2.5	5
11-17	1240	4.0	2.53	4
1- 5-70	1410	0	3.53	10
2-24	1340	4.5	4.79	16
3-30	1440	--	10.3	76
5-11	1325	9.0	.07	14
5-26	1345	14.5	1.02	16
6-15	1250	13.5	2.85	16
7-20	1825	14.5	.96	13
2-22-71	1425	5.0	3.54	6
4-13	0855	3.5	10.1	34
4-15	1525	8.0	11.3	68
4-30	0830	8.5	--	44
6- 3	1220	12.0	11.1	54
6- 7	1420	13.5	8.3	35
12445000. Okanogan River near Tonasket Lat 48°37'57", long 119°27'38"				
5-20-69	0815	13.0	13,000	82
7-15	1550	20.5	2,090	8
8-29	1110	--	640	2
10- 9	0835	12.0	1,420	4
11-20	1105	4.0	1,140	3
1- 8-70	1115	0	790	3
2-27	0815	4.0	679	4
5-20	1430	13.5	--	71
5-26	1205	13.0	9,740	156
6-11	1300	13.5	--	74
8- 6	1600	25.0	585	4
4-30-71	0915	10.0	3,800	84
6- 2	1700	11.0	17,100	152
6-10	1100	13.0	--	89
6-15	1605	13.0	15,000	99
6-17	1600	14.5	12,500	86
6-29	1435	15.5	8,040	48
12447200. Okanogan River at Malott Lat 48°16'53", long 119°42'12"				
5-22-69	0755	11.5	14,300	82
7- 8	1815	18.0	2,920	18
8-13	0940	21.5	819	8
9-24	1430	18.0	954	4
11- 5	1150	10.5	1,280	2
12- 9	0740	3.0	1,010	1
2-24-70	1600	3.0	721	2
4-14	1120	8.0	914	6
5-20	1530	15.0	--	88
6- 3	0915	13.0	9,670	56
6-11	1155	14.0	8,950	84
8-25	0850	20.0	376	4
4-30-71	1020	12.0	3,710	97
5- 4	1600	9.0	6,390	248
6- 2	1545	11.5	17,700	142
6- 4	1230	11.5	19,500	130
6-15	1445	13.5	15,800	117
6-17	1720	14.5	13,200	88
6-29	1410	15.5	8,830	54

TABLE 10.--Suspended-sediment concentrations at three reconnaissance-sampling sites in the Okanogan River basin. Sites are shown on plate 1 and are located only by latitude and longitude. Water discharge was estimated from measured cross-section geometry and surface velocity

Date	Time (24 hr)	Water temperature (°C)	Discharge (cfs)	Suspended-sediment concentration (mg/l)
Sinlahekin Creek Lat 48°50'00", long 119°38'52"				
6- 3-71	0945	10.5	50	50
6-16	0935	13.0	30	21
Palmer Creek Lat 48°55'25", long 119°39'18"				
6-11-70	1455	17.0	1,500	39
Similkameen River at Oroville Lat 48°56'04, long 119°26'28"				
5-20-70	1350	11.5	--	41
6-11	1350	11.0	--	42
6- 3-71	1030	8.5	--	143
6-16	0720	10.0	--	76
6-17	1345	11.5	--	74
6-29	1645	14.0	--	29

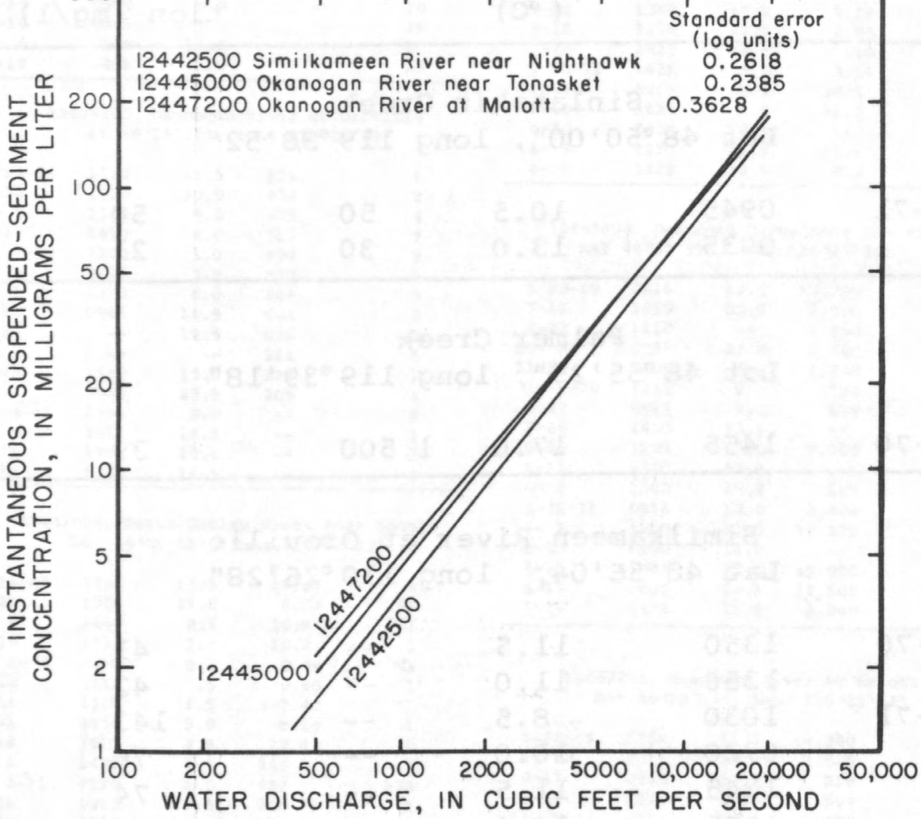

FIGURE 6.--Relation of suspended-sediment concentration to water discharge at three sites in the Okanogan River basin.

Methow River Basin

The Methow River basin (F in fig. 2) covers 1,794 square miles in the northwestern part of the study area (pl. 1). The Methow River and upper tributaries head on the eastern slope of the Cascade Range, then flow east and south to the main-stem valley and its confluence with the Columbia River at Pateros. Altitudes in the basin range from 8,844 feet on Silver Star Mountain to about 1,400 feet at the mouth of the river.

The annual precipitation ranges from less than 10 inches near Pateros to more than 80 inches near the crest of the Cascade Range (pl. 1). Most of the precipitation falls during the period November-March, largely as snow, although at the higher altitudes sufficient precipitation falls throughout the year to maintain a good vegetative cover. The snow melts generally during April-July, and produces about 80 percent of the annual runoff.

The mountainous parts of the Methow River basin generally are rocky and have only thin soils and, thus, the sediment yield is low. In the lower parts of the basin, downstream from Mazama, the river flows in a low-gradient alluvial valley where the deposits are being continually reworked by the stream. The cropland is restricted to this lower part of the valley (fig. 2), where the soils are seldom exposed to heavy rainfall; the sediment yield there is generally low.

Suspended-sediment concentrations are generally below 20 mg/l except during spring runoff. Samples were collected periodically at three sites in the basin and on a reconnaissance basis at five sites (pl. 1). Measured suspended-sediment concentrations during 1969-71 ranged from less than 1 mg/l at three sites to 601 mg/l in Beaver Creek; the highest concentration observed in the Methow River was 256 mg/l, near Pateros.

Sediment samples collected in the Methow River basin indicate that suspended-sediment concentrations (1) are greater in the Methow River at Twisp and near Pateros than in the tributaries, (2) generally increase downstream in the Methow River below Winthrop, (3) in the Twisp River at its mouth are similar to those in the Methow River at its confluence with the Twisp River, (4) are generally less in the Chewack River than in the Methow River upstream from its confluence with the

Chewack River, and (5) at low flows are similar throughout the basin.

The Methow River is continually reworking the sediments in its channel, and little fine sediment is available in the bed. The channel is fairly stable at low and medium flows, but at high flows the banks are eroded largely by undercutting, resulting in transport of material sloughed into the channel. Tributary stream channels are generally stable in most places because banks with good vegetative cover retard erosion except at high flows, when the streams rework adjacent glacial deposits. However, because the suspended sediment is largely sand, the streams remain fairly clear.

The estimated annual suspended-sediment yields per square mile above various sampling sites in the Methow River basin are as follows: (1) Methow River near Pateros, 50 tons; (2) Methow River at Twisp, 50 tons; (3) Chewack River, 30 tons; (4) Twisp River, 50 tons; (5) Methow River above Weeman Bridge, 50 tons; and (6) Methow River between Weeman Bridge and Twisp and excluding Chewack River, 50 tons.

Streamflow records have been collected from 1960 to the present (1970) at the station, Beaver Creek below South Fork, near Twisp (12449600). By using these records and the suspended-sediment data collected during 1969-71, the annual suspended-sediment yield in Beaver Creek upstream from this site was estimated to be less than 2 tons per square mile during the 10-year period of streamflow record. However, because extreme floods transport most of the sediment in Beaver Creek and because an extreme flood did not occur during this 10-year period, a longer term annual sediment yield of 10 tons per square mile for Beaver Creek seems a reasonable estimate. Sediment yields of small streams tributary to the Methow River downstream from its confluence with the Twisp River are similar to that of Beaver Creek. Assuming that the tributary areas also yield about 10 tons per square mile over a long period, the channel erosion in the Methow River in this reach would average about 20,000 tons annually. The suspended-sediment concentrations observed at periodic- and reconnaissance-sampling sites in the Methow River basin during the study period are listed in tables 11 and 12, respectively, and the relation of suspended-sediment concentration to water discharge in the Methow River near Pateros is shown in figure 7.

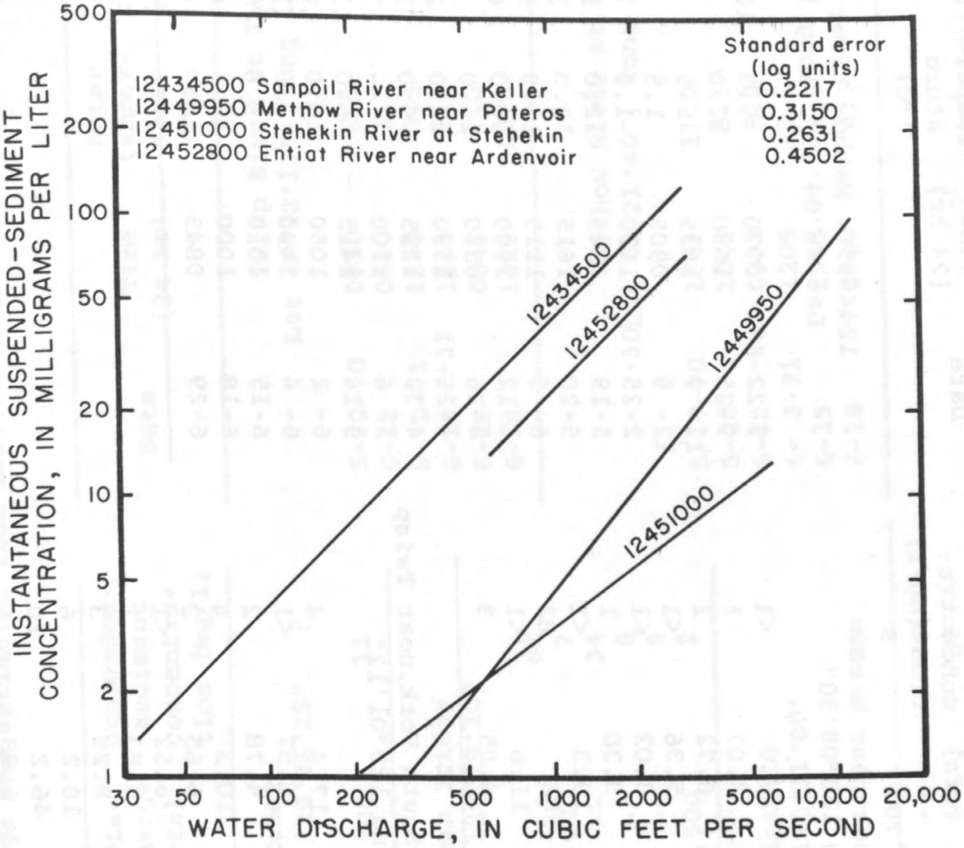

FIGURE 7.--Relation of suspended-sediment concentration to water discharge at four sites in the Sanpoil, Chelan, Methow, and Entiat River basins.

TABLE 11.--Suspended-sediment concentrations at three periodic-sampling sites in the Methow River basin. Sites are shown on plate 1 and listed in table 1

12447390. Andrews Creek near Mazama
Lat 48°49'28", long 120°08'50"

Date	Time (24 hr)	Water temperature (°C)	Discharge (cfs)	Suspended-sediment concentration (mg/l)
7-17-69	1030	6.5	16.8	<1
8-28	1100	6.0	4.07	1
10-10	1210	4.0	6.72	1
11-21	1210	1.0	5.36	<1
2-12-70	1245	1.0	3.02	<1
4-14	1210	1.5	3.30	1
5-15	1135	2.0	19.3	<1
6- 3	--	5.5	382	82
7-24	1210	8.5	11.6	<1
8-26	1230	--	4.05	3

12449600. Beaver Creek below South Fork, near Twisp
Lat 48°25'44", long 120°01'12"

Date	Time (24 hr)	Water temperature (°C)	Discharge (cfs)	Suspended-sediment concentration (mg/l)
7-18-69	0915	9.0	17.4	4
8-28	1530	10.0	6.57	<1
10- 9	1530	5.5	4.78	2
11-20	1540	0	10.3	4
1- 9-70	0920	0	6.65	2
2-27	1200	.5	6.52	<1
4- 2	1350	2.0	6.83	1
4-13	1620	2.0	8.29	3
5-14	1635	6.0	18.2	6
6- 4	1705	11.0	46.2	20
7-23	1205	11.0	6.88	1
8-26	1630	--	4.44	6
5- 6-71	1515	7.0	--	85
5-13	1040	3.5	--	601

12449950. Methow River near Pateros
Lat 48°04'39", long 119°59'02"

Date	Time (24 hr)	Water temperature (°C)	Discharge (cfs)	Suspended-sediment concentration (mg/l)
5-22-69	0930	9.5	10,800	76
9-25	1030	12.0	428	1
11- 7	1035	5.5	443	1
12- 9	0905	1.5	354	<1
2-25-70	1130	1.0	301	<1
5-19	1645	12.0	3,900	28
5-20	1615	12.0	3,700	42
6- 3	1115	10.5	9,840	143
6-12	1000	10.0	4,440	12
8-26	0830	16.0	225	2
4-26-71	1530	13.0	2,630	34
4-30	1125	9.0	3,370	28
5- 6	1100	--	7,700	69
5-14	1415	6.0	13,700	256
6- 2	1050	10.0	10,600	98
6- 4	1400	10.0	11,900	125
6-15	1010	9.0	7,050	49
6-18	1000	10.5	6,100	24
6-29	0845	10.0	4,380	5

TABLE 12.--Suspended-sediment concentrations at five reconnaissance-sampling sites in the Methow River basin. Sites are shown on plate 1 and are located only by latitude and longitude. Water discharge was estimated from measured cross-section geometry and surface velocity

Date	Time (24 hr)	Water temperature (°C)	Discharge (cfs)	Suspended-sediment concentration (mg/l)
Early Winters Creek Lat 48°36'00", long 120°26'25"				
6- 2-71	1305	8.5	500	12
Methow River at Weeman Bridge Lat 48°32'40", long 120°19'20"				
5-20-70	0845	6.0	--	62
6-12	0730	5.5	2,000	7
6- 2-71	1305	8.5	--	34
6-15	1140	8.0	--	8
6-18	0750	6.5	--	9
6-29	1230	9.5	2,500	2
Chewack River at Winthrop Lat 48°28'30", long 120°11'00"				
5-20-70	0815	6.0	--	30
6-12	0800	6.0	1,500	8
6- 2-71	1400	9.5	--	30
6-15	1210	8.5	--	20
6-18	0820	8.5	--	22
6-29	1255	10.0	1,200	2
Twisp River at Twisp Lat 48°22'12", long 120°08'51"				
5-20-70	0930	8.5	--	27
6-12	0820	6.0	--	8
6- 2-71	1230	8.5	900	62
6-15	1230	9.0	--	12
6-18	0845	7.0	--	10
6-29	1315	10.0	500	2
Methow River at Twisp Lat 48°21'40", long 120°06'50"				
5-19-70	1745	11.0	--	25
5-20	1045	8.5	--	28
6-12	0900	8.0	--	8
6- 2-71	1205	9.5	--	126
6-15	1255	9.5	--	24
6-18	0900	8.5	--	20

Chelan River Basin

The Chelan River basin (G in fig. 2) covers 924 square miles on the east slope of the Cascade Range, with the main valley being occupied by the Stehekin River in its upper reaches, by Lake Chelan for about 60 miles to the town of Chelan, and by the Chelan River which flows for about 4 miles to its mouth at Lake Entiat on the Columbia River (pl. 1). Lake Chelan and the Stehekin River valley are flanked by rugged mountains, with peaks generally 7,000 to 9,000 feet in altitude. The altitudes in the basin range from 9,511 feet on Bonanza Peak to about 707 feet, the normal elevation of Lake Entiat behind Rocky Reach Dam. The Chelan River originates as the outlet of Lake Chelan; however, most of the water flows through penstocks to a powerplant and to the Columbia River.

Annual precipitation in the Chelan River basin ranges from less than 10 inches near the mouth of the Chelan River to more than 150 inches along the crest of the Cascade Range (pl. 1). Most of the precipitation in the mountains falls as snow; snowmelt runoff occurs during the period May-August. Occasional thunderstorms produce rapid runoff which transports considerable quantities of sediment.

Most of the Chelan River basin is rugged, forested mountains where bedrock is overlain by thin soils (fig. 2). Farming in the basin is restricted largely to orchards on glacial outwash terraces along the lower reaches of Lake Chelan. Surface runoff and soil erosion from the orchards are very low.

Suspended-sediment samples in the Chelan River basin were obtained only from the Stehekin River near Stehekin (tables 1 and 13). Observed suspended-sediment concentrations during 1969-71 ranged from 1 to 22 mg/l (table 1). The annual suspended-sediment yield of the basin above the sampling site on the Stehekin River is about 45 tons per square mile. The relation of suspended-sediment concentration to water discharge there is shown in figure 7.

The yield from the lower part of the Chelan River basin is estimated to be 10 tons per square mile, similar to that in the lower part of the Okanogan River basin. An increase in sediment transport was noted in streams draining an area of 104 square miles along the lower reach of Lake Chelan, which was burned over by forest fires in 1970.

TABLE 13.--Suspended-sediment concentrations at a periodic-sampling site at Stehekin, Chelan River basin. Site is shown on plate 1 and listed in table 1

Date	Time (24 hr)	Water temper-ature (°C)	Dis-charge (cfs)	Suspended-sediment concentra-tion (mg/l)
12451000. Stehekin River at Stehekin Lat 48°19'40", long 120°41'21"				
7-10-69	1030	11.5	2,450	10
9-25	1030	8.5	1,380	5
11- 5	1155	5.0	583	2
12-10	1130	3.0	265	1
1-22-70	1150	0	195	1
4-15	1125	5.5	706	2
6- 5	0800	5.5	7,160	22
7-16	1100	10.5	1,890	8
8-26	1045	10.0	838	6
5- 5-71	1100	5.0	5,020	12
6-16	1100	6.0	3,540	2

Entiat River Basin

The Entiat River basin (H in fig. 2) covers 419 square miles in the Entiat and Chelan Mountains of the Cascade Range, in the western part of the study area (pl. 1). The basin ranges in altitude from 9,082 feet on Mount Maude to about 700 feet, the normal altitude of Lake Entiat behind Rocky Reach Dam on the Columbia River.

Annual precipitation in the basin ranges from less than 10 inches at Entiat to more than 70 inches near Mount Maude (pl. 1). Much of the precipitation falls as snow at the higher altitudes, and most of the runoff is from snowmelt which usually occurs during May through July. Occasional thunderstorms cause rapid runoff for short periods which infrequently transports large quantities of sediment but generally for only short distances.

A generally thin soil mantle that absorbs much of the rainfall overlies bedrock in most of the Entiat River basin. Farming on the flood plain and adjacent terraces has had little effect on the sediment transport because the soil is seldom exposed to intense rainfall.

Suspended-sediment samples were collected periodically from the Entiat River near Ardenvoir (12452800), and on a reconnaissance basis near its mouth and from the Mad River.

Suspended-sediment concentrations measured during 1969-71 ranged from less than 1 to 188 mg/l (table 1). The high concentration occurred during a period when debris was being cleared from the channel of the Entiat River above Ardenvoir. Under normal conditions the maximum concentration in the Entiat River near Ardenvoir was 68 mg/l, measured during a concurrent water discharge of 2,130 cfs. The probable annual suspended-sediment yield of the basin downstream from the gaging station near Ardenvoir was estimated to be less than 10 tons per square mile.

The suspended-sediment concentrations in the Mad River near its mouth, measured on a reconnaissance basis, were generally low, with the highest concentration of 29 mg/l occurring during spring runoff. The annual suspended-sediment yield of the drainage area was estimated to be less than 10 tons per square mile.

The suspended-sediment concentrations measured at periodic- and reconnaissance-sampling sites in the Entiat River basin during the study period are listed in tables 14 and 15, respectively, and the relation of suspended-sediment concentration to water discharge in the Entiat River near Ardenvoir is shown in figure 7.

TABLE 14.--Suspended-sediment concentrations at a periodic-sampling site in the Entiat River basin. Site is shown on plate 1 and listed in table 1

Date	Time (24 hr)	Water temperature (°C)	Discharge (cfs)	Suspended-sediment concentration (mg/l)
12452800. Entiat River near Ardenvoir Lat 47°48'31", long 120°24'47"				
5-19-69	1420	10.0	1,570	16
7-11	1010	10.0	480	4
9-24	1200	9.0	161	3
12-11	1000	.5	59.9	13
1-23-70	1145	.5	62.1	1
2-26	1010	.5	59.4	<1
4-15	1635	7.0	111	1
5-20	1745	10.5	770	20
6- 4	0900	6.0	2,600	39
6-11	0745	6.0	--	21
7-15	1630	18.0	286	4
8-25	1715	16.5	109	1
4-30-71	1300	8.0	458	38
5- 4	1510	7.0	1,130	188
5-14	0930	4.5	2,130	68
6- 2	0820	6.0	1,920	32
6-15	0750	5.0	1,600	24
6-18	1215	7.0	1,420	22
6-29	0615	5.0	1,120	24

TABLE 15.--Suspended-sediment concentrations at two reconnaissance-sampling sites in the Entiat River basin. Sites are shown on plate 1 and are located only by latitude and longitude. Water discharge was estimated from measured cross-section geometry and surface velocity

Date	Time (24 hr)	Water temperature (°C)	Discharge (cfs)	Suspended-sediment concentration (mg/l)
Mad River at Ardenvoir Lat 47°44'13", long 120°22'03"				
5-20-70	1735	10.0	200	5
6-11	0730	6.0	200	8
4-30-71	1325	9.5	100	29
6- 2	0845	6.5	300	20
6-15	0815	5.5	300	10
6-18	1235	7.0	150	14
6-29	0640	5.5	100	12
Entiat River near mouth Lat 47°39'18", long 120°14'58"				
5-19-69	1420	10.0	--	16
5-20-70	1805	11.5	--	15
6-11	0800	6.5	--	18
4-30-71	1345	10.0	--	38
6- 2	0910	8.5	--	42
6-15	0845	9.0	--	26
6-18	1300	9.0	--	18
6-29	0700	6.5	--	20

Wenatchee River Basin

The Wenatchee River basin (J in fig. 2) covers 1,327 square miles in the Wenatchee and Entiat Mountains on the eastern slope of the Cascade Range (pl. 1). The basin altitudes range from 9,415 feet on Mount Stuart to 606 feet, the normal altitude of the reservoir pool behind Rock Island Dam on the Columbia River. Most of the farming occurs in the lower eastern part of the basin, which includes several valleys separated by low mountains and plateaus.

The annual precipitation (pl. 1) ranges from less than 10 inches at Wenatchee to more than 150 inches near the crest of the Cascade Range. Most of the precipitation at the higher altitudes falls as snow; the snowmelt and major part of the runoff occurs during April through July (fig. 1).

Much of the precipitation at the low altitudes is absorbed by the generally sandy soils of the farmlands (fig. 2), although thunderstorms occasionally produce sufficient runoff to erode large quantities of the soil. Nearly instantaneous peak flows are produced by localized thunderstorms of short duration. These short-period flows transport the eroded materials only short distances and the sediment seldom reaches the major stream channels. During occasional intense thunderstorms some sediment deposition has occurred in housing areas above Wenatchee where urban development has extended into the steep and arid canyons. Such rapid erosion and deposition in steep and semiarid canyons are prevalent in the Wenatchee River basin. At the higher altitudes in the basin, where greater precipitation sustains a good vegetative cover, rapid erosion is prevented except during extreme floodflows. Also, the coarse soils of the mountainous areas absorb much of the rainfall, causing little sediment to be transported from there except during periods of snowmelt.

Suspended-sediment samples in the Wenatchee River basin were collected periodically at six gaging-station sites and on a reconnaissance basis at nine sites during 1969-71 (pl. 1). Suspended-sediment concentrations measured ranged from less than 1 mg/l at many sites to 236 mg/l at the station, Mission Creek above Sand Creek, near Cashmere. The higher concentrations occurred during runoff from intense rainfall and (or) rapid snowmelt. The basin's streams generally had low suspended-sediment concentrations, only infrequently being as much as 50 mg/l during high flows. The higher concentrations in the basin were observed in Mission Creek, Napeequa River and Chiwawa River. During low flows, suspended-sediment concentrations are similar throughout the basin.

The estimated annual suspended-sediment yields per square mile in the Wenatchee River basin are as follows, in downstream order: (1) White River basin, 260 tons; (2) Chiwawa River basin, 40 tons; (3) Wenatchee River basin upstream from Plain, 30 tons; (4) Icicle Creek basin, 40 tons; and (5) entire Wenatchee River basin (upstream from Monitor), 30 tons. Many modifications are occurring in the channels of the Little Wenatchee, White, and Chiwawa Rivers, but other channels are fairly stable except for some local erosion. The high yield in the White River basin reflects the glacial activity in the headwater areas. The suspended-sediment concentrations measured at periodic- and reconnaissance-sampling sites in the Wenatchee River basin during the study period are listed in tables 16 and 17, respectively, and the relations of suspended-sediment concentration to water discharge at six sites in the basin are shown in figure 8.

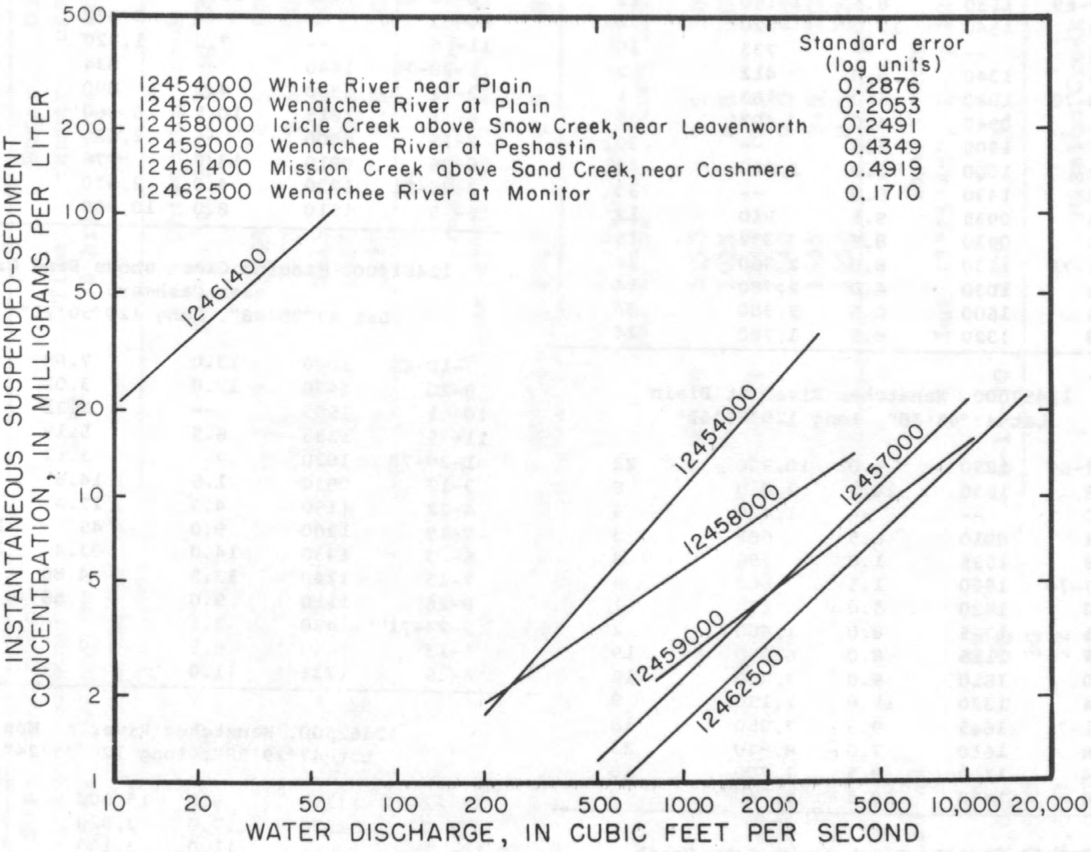

FIGURE 8.--Relation of suspended-sediment concentration to water discharge at six sites in the Wenatchee River basin.

TABLE 16.--Suspended-sediment concentrations at six periodic-sampling sites in the Wenatchee River basin. Sites are shown on plate 1 and listed in table 1

12454000. White River near Plain
Lat 47°52'27", long 120°52'09"

Date	Time (24 hr)	Water temperature (°C)	Discharge (cfs)	Suspended-sediment concentration (mg/l)
7- 8-69	1130	8.5	1,160	12
8-19	1540	12.0	320	4
9-30	--	--	733	10
11- 4	1340	6.0	412	2
3-10-70	1040	1.0	183	1
4-21	0940	4.0	407	2
5-21	1305	5.5	--	30
6- 2	1000	7.0	2,820	49
6-10	1430	6.0	--	30
7-14	0935	9.5	910	12
8-25	0930	8.5	337	15
6- 1-71	1530	8.0	2,360	40
6- 8	1030	4.0	2,780	14
6-14	1600	6.5	2,300	33
6-28	1320	6.5	1,780	24

12457000. Wenatchee River at Plain
Lat 47°45'38", long 120°39'42"

Date	Time (24 hr)	Water temperature (°C)	Discharge (cfs)	Suspended-sediment concentration (mg/l)
5-22-69	1250	9.0	10,900	22
7- 8	1630	14.5	2,810	8
9-30	--	--	1,460	4
11- 4	0910	6.5	683	3
12-29	1525	1.0	556	4
1-27-70	1500	1.5	660	4
3-10	1620	5.0	630	1
4-21	1335	8.0	1,400	2
5-21	1115	8.0	6,000	19
6-10	1610	9.0	7,400	16
7-14	1320	15.0	2,150	9
6- 1-71	1645	9.5	7,950	18
6- 8	1610	7.0	8,840	33
6-14	1710	9.5	7,700	18
6-28	1450	10.5	6,040	8

12458000. Icicle Creek above Snow Creek, near Leavenworth
Lat 47°32'28", long 120°43'08"

Date	Time (24 hr)	Water temperature (°C)	Discharge (cfs)	Suspended-sediment concentration (mg/l)
7- 9-69	1100	11.0	410	8
8-19	1430	12.0	154	<1
9-29	1030	11.0	215	3
11- 3	1625	6.5	143	1
1-28-70	1050	1.0	133	<1
3-11	0920	1.0	158	2
4-22	0915	4.0	310	1
5-21	0945	4.0	1,870	9
6- 3	1015	--	4,090	16
6-10	1115	5.5	--	6
8-25	1510	11.5	131	<1
6- 1-71	1335	8.5	2,080	8
6- 9	1120	4.5	2,080	7
6-14	1445	9.5	2,150	16
6-28	1140	8.0	1,550	4

12459000. Wenatchee River at Peshastin
Lat 47°35'00", long 120°36'46"

Date	Time (24 hr)	Water temperature (°C)	Discharge (cfs)	Suspended-sediment concentration (mg/l)
8-20-69	0900	16.5	878	8
10- 1	--	--	3,070	29
11- 5	--	7.0	1,720	5
1-28-70	1440	--	834	1
3-11	1320	4.0	890	1
6- 1	1815	10.5	8,360	16
7-15	0900	--	2,680	8
8-26	0910	13.0	776	<1
2-24-71	1220	4.0	2,570	2
6- 9	1510	8.0	10,900	8

12461400. Mission Creek above Sand Creek, near Cashmere
Lat 47°25'48", long 120°30'20"

Date	Time (24 hr)	Water temperature (°C)	Discharge (cfs)	Suspended-sediment concentration (mg/l)
7-10-69	1040	13.0	7.88	10
8-20	1430	17.0	3.02	<1
10- 1	1505	--	3.21	2
11- 5	1335	6.5	5.19	20
1-29-70	1030	0	3.12	<1
3-12	0850	1.5	14.6	2
4-22	1150	4.5	17.4	9
5-19	1200	9.0	45	236
6- 3	1430	14.0	33.4	134
7-15	1240	13.5	4.86	6
8-26	1110	9.0	1.66	2
2-24-71	1450	3.5	--	10
5-13	1650	8.5	50	98
6- 9	1735	11.0	--	8

12462500. Wenatchee River at Monitor
Lat 47°29'58", long 120°25'24"

Date	Time (24 hr)	Water temperature (°C)	Discharge (cfs)	Suspended-sediment concentration (mg/l)
5-22-69	1115	9.0	15,800	26
7-10	1530	17.0	3,820	9
10- 2	--	11.0	3,130	5
11- 6	1015	6.5	1,660	2
1-26-70	1700	1.5	973	2
3- 9	1620	10.5	1,100	1
4-20	1500	8.0	2,210	5
5-21	0810	8.0	9,100	21
6- 1	1500	10.5	8,380	11
6-10	1705	11.0	--	20
7-13	1640	18.5	3,030	4
8-24	1530	23.5	598	1
4-26-71	1330	8.5	--	16
6- 1	1800	10.0	11,800	29
6- 4	1540	10.5	11,500	24
6- 7	1620	6.5	12,900	12
6-14	1810	10.0	11,300	9
6-18	--	9.5	9,640	9
6-28	1555	11.0	8,630	9

TABLE 17.--Suspended-sediment concentrations at nine reconnaissance-sampling sites in the Wenatchee River basin. Sites are shown on plate 1 and are located only by latitude and longitude. Water discharge was estimated from measured cross-section geometry and surface velocity

Date	Time (24 hr)	Water temper- ature (°C)	Dis- charge (cfs)	Suspended- sediment concentra- tion (mg/l)
Napeequa River Lat 47°55'19", long 120°53'42"				
6-10-70	1400	7.0	400	50
Little Wenatchee River Lat 47°51'00", long 120°56'39"				
5-21-70	1210	5.5	1,000	4
6-10	1450	5.5	2,000	4
6- 1-71	1510	6.0	1,600	2
6-14	1630	7.0	2,000	9
6-28	1345	5.5	1,200	4
Nason Creek Lat 47°48', long 120°43'				
5-21-70	1405	8.0	700	11
6-10	1315	6.5	2,000	23
6- 1-71	1435	8.5	1,000	18
6-14	1535	9.0	1,000	14
6-28	1300	8.5	700	2
Chiwawa River Lat 47°48', long 120°38'				
5-21-70	1135	6.0	--	66
6-10	1545	8.5	2,000	28
6- 1-71	1615	9.5	2,500	30
6-14	1645	8.5	3,000	22
6-28	1420	5.5	2,000	20

Date	Time (24 hr)	Water temper- ature (°C)	Dis- charge (cfs)	Suspended- sediment concentra- tion (mg/l)
Chiwaukum Creek Lat 47°41'33", long 120°44'00"				
5-21-70	1045	4.5	500	6
6-10	1250	6.5	500	4
6- 1-71	1415	8.0	500	6
6-14	1515	8.5	300	4
6-28	1235	8.0	200	2
Peshastin Creek Lat 47°25'26", long 120°39'30"				
5-19-70	1050	6.5	80	6
Peshastin Creek Lat 47°32'55", long 120°36'32"				
5-19-70	1120	8.5	300	14
6-10	1025	6.5	700	8
4-26-71	1245	6.5	--	54
6- 1	1240	9.0	600	13
6-14	1345	9.5	300	6
6-28	1050	8.5	120	4
Sand Creek Lat 47°25'48", long 120°30'26"				
5-19-70	1405	11.0	10	30
Mission Creek Lat 47°31'05", long 120°28'20"				
5-19-70	1505	13.0	30	64

Yakima River Basin

The Yakima River basin (K in fig. 2) covers 6,155 square miles in the southwestern part of the upper Columbia River basin (pl. 1). The Yakima River originates near the crest of the Cascade Range and flows in a valley that alternately narrows and widens in several reaches along its course before reaching the Columbia River at Richland. The altitude of the basin ranges from 7,986 feet on Mount Daniel at the range crest to about 340 feet at Lake Wallula on the Columbia River near Richland. The annual precipitation in the basin ranges from less than 10 inches along the lower Yakima River to more than 140 inches near the crest of the Cascade Range (pl. 1).

The runoff in the Yakima River basin is largely from snowmelt, although winter storms moving over the crest of the Cascade Range occasionally release heavy rains that cause high runoff. The peak winter runoff usually occurs in December. Winter runoff similar in pattern to that occurring at the station Yakima River at Kiona (12510500; fig. 1) occurs in the upper Yakima, Tieton, and Bumping River basins. Some winter runoff is used to partly fill Keechelus, Kachess, and Cle Elum Lakes in the upper Yakima River basin and Bumping Lake and Tieton Reservoir in the Naches River basin. The high winter flows during January and February in the Yakima River at Kiona are the result of early snowmelt in the lower valley and water released from the reservoirs to provide for flood storage during the spring runoff. Much spring runoff is used to fill the reservoirs (usually by May); the remainder either is used for irrigation or is discharged to the Columbia River.

The eastern slopes of the Cascade Range are underlain by bedrock and have a thin soil mantle. In the vicinity of Yakima the tributary valleys and main valley contain loam soils (Smith and others, 1958) underlain by an unknown thickness of coarse-grained alluvial materials. Most of the cultivated farming in the basin is in areas of loam soils. Erosion of the soils in the mountainous areas, where the heavy precpitation occurs, is minimized by the protection afforded by the vegetation. When logging operations and road construction expose the soil, the fine materials are eroded and removed during periods of intense rainfall.

The quantity of sediment transported in the Yakima River basin is influenced by the areal distribution of precipitation and erodible soils. Although the highest precipitation in the basin occurs at the higher altitudes near the crest of the Cascade Range, the thin rocky soils there preclude much erosion and transport of sediment in the mountain reaches of the streams. On the other hand, the finer, more easily transported sediments are in the lower valleys where the precipitation and slope are less. There, erosion and sediment transport are increased, by the application of irrigation water to the fine soils, although artificial control of the streamflow at the same time tends to reduce sediment transport.

The quantity of sediment discharged from the upper Yakima River basin is very small because much of the water passes through lakes and the generally thin soils are protected by a good vegetative cover. During 1969-71, the suspended-sediment concentrations were generally less than 10 mg/l at the gaging station on the Yakima River at Cle Elum; the maximum concentration measured there was 16 mg/l. The erosion in the Yakima River channel is reduced significantly by the control of high streamflows at Keechelus, Kachess, and Cle Elum Lakes and by the diversion of the water from the river downstream from these reservoirs.

In many places the tributaries to the Yakima River in the upper drainage--the Swauk, Taneum, Naneum, Manastash, Umtanum, Wenas, Selah, and Wilson Creeks and Teanaway River--flow through narrow canyons eroded in the bedrock. The probability of high flows and severe erosion in the narrow valley floors, which are underlain by coarse sand, gravel, and cobbles is very small because (1) much of the precipitation falls as snow, (2) the streamflow is decreased by irrigation diversions, and (3) the canals and irrigation-return-flow ditches support heavy vegetative cover in and along their channels.

The suspended-sediment concentrations in the upper drainage were usually less than 20 mg/l, except in Wilson Creek where irrigation water erodes the soil and moves some sediment to the creek. Concentrations in Wilson Creek generally ranged from 30 to 200 mg/l, with measured concentrations during 1969-71 ranging from 20 to 367 mg/l. The major tributaries to Wilson, Naneum, Coleman, Cooke, Trail, Caribou, Parke, Badger, and Cherry Creeks originate at higher altitudes north and east of Ellensburg and discharge into a complex system of distributaries, irrigation canals, and return-flow ditches. Much of the sediment transported from the high altitudes is deposited in the canal system or on the farmland, where it is again eroded during intense precipitation and transported by the runoff and by excess irrigation water.

Much of the precipitation in the Naches River basin falls as snow and most of the resulting melt-water runoff is stored--usually for irrigation--in Bumping Lake and Tieton Reservoir. However, occasional heavy rains in the winter, and early snow-melt occurring before the irrigation season, cause high stream-flows which result in some channel changes and considerable movement of bed material. The upper parts of the basin have good vegetative cover, whereas soils in the lower parts of the basin, where the precipitation is lighter, are more exposed to severe erosion by intense precipitation. The suspended-sediment concentrations were low, usually less than 20 mg/l, although a concentration of 264 mg/l was measured during high streamflow at the station, Naches River below Tieton River, near Naches.

The highest suspended-sediment concentrations in the Naches River basin were measured in Short and Dirty Creek, and in both Milk Creeks--one a tributary to the Naches River and the other a tributary to the Tieton River. The Milk Creek tributary to Naches River flows over rhyolite bedrock and some interbedded tuff beds, while the Milk Creek and Short and Dirty Creek, tributaries to the Tieton flow over landslide and mudflow deposits at the lower end of Tieton Reservoir.

Suspended-sediment concentrations in the large tributaries to the Naches River--Bumping River, Tieton River, Little Naches River, and Rattlesnake Creek--seldom exceed 100 mg/l in most years and probably do not exceed 500 mg/l during extreme floods. However, concentrations in the smaller tributaries--both Milk Creeks and Short and Dirty Creek--may increase to more than 1,000 mg/l during large floods. During 1969-71 the highest measured suspended-sediment concentration in the Naches River basin was 477 mg/l, in the Milk Creek tributary to Naches River; usually the concentrations in the basin's streams were less than 20 mg/l.

The South Fork Tieton River has the highest suspended-sediment yield in the Naches River basin, although insufficient data are available to define its magnitude. Rattlesnake and Nile Creeks generally have suspended-sediment concentrations higher than those in adjacent streams, their basins' sediment yields are lower than those of the Bumping, American, and Little Naches River basins because the runoff of the former basins is less than one-half that of the latter basins.

The major tributaries to the Yakima River south of the city of Yakima are Ahtanum, Toppenish, and Satus Creeks, which originate in the mountains southwest and south of Yakima. These streams flow in narrow canyons for short distances, then onto the alluvial plain of the lower Yakima River valley, where most of the streamflow is diverted for irrigation.

Although the diversion of much of the water of the lower Yakima River to irrigation canals reduces the magnitude of channel erosion, some erosion of the farmland occurs as a result of irrigation. Also, many small, intermittent streams which discharge directly into the canals carry and deposit sediment there, which is then either dredged from the canals or carried onto the land by the water.

The suspended-sediment concentrations in the Ahtanum Creek basin are generally less than 20 mg/l, and during 1969-71 the observed concentrations ranged from less than 1 to 242 mg/l (table 1). At equal water discharges, the concentrations were generally less in the North Fork than in the South Fork.

Because precipitation is light, and much of the streamflow and accompanying sediment in the lower Yakima River valley is diverted onto the farmland, the stream channels have become overgrown with vegetation. Generally, because water is not diverted during periods of high streamflow, some channel erosion occurs then; however, because the gradients are flat the water is ponded in the lower reaches and the suspended sediment tends to settle--especially in Toppenish and Satus Creeks. Suspended-sediment concentrations of 2,430 mg/l in Dry Creek and 1,740 mg/l in lower Satus Creek were measured during a large flood.

The small basins drained to the middle reach of the Yakima River from the east (Squaw and Selah Creek basins and Moxee Valley) and to the Cold Creek basin in the lower Yakima River valley receive little precipitation and much sediment in this area is transported by wind. The unfarmed parts of the area have good grass cover and absorb much of the precipitation. Runoff during periods of intense rainfall in these basins erodes sediment from farmland and steep slopes and this is subsequently transported by the streams.

The high sediment concentration in the Yakima River in the spring results largely from the high discharges resulting from snowmelt in the mountains, and from the lack of reserve storage in the basin.

On the basis of sediment data collected during 1969-71 and flow-duration curves, the average annual suspended-sediment yield of the Yakima River basin is estimated to be 50 tons per square mile. The estimated average annual yields for the basin are shown in figure 3 and listed in table 1. The suspended-sediment concentrations measured at periodic- and reconnaissance-sampling sites in the basin during the study period are listed in tables 18 and 19, respectively, and the relations of suspended-sediment concentration to water discharge at 11 sites in the basin are shown in figure 9.

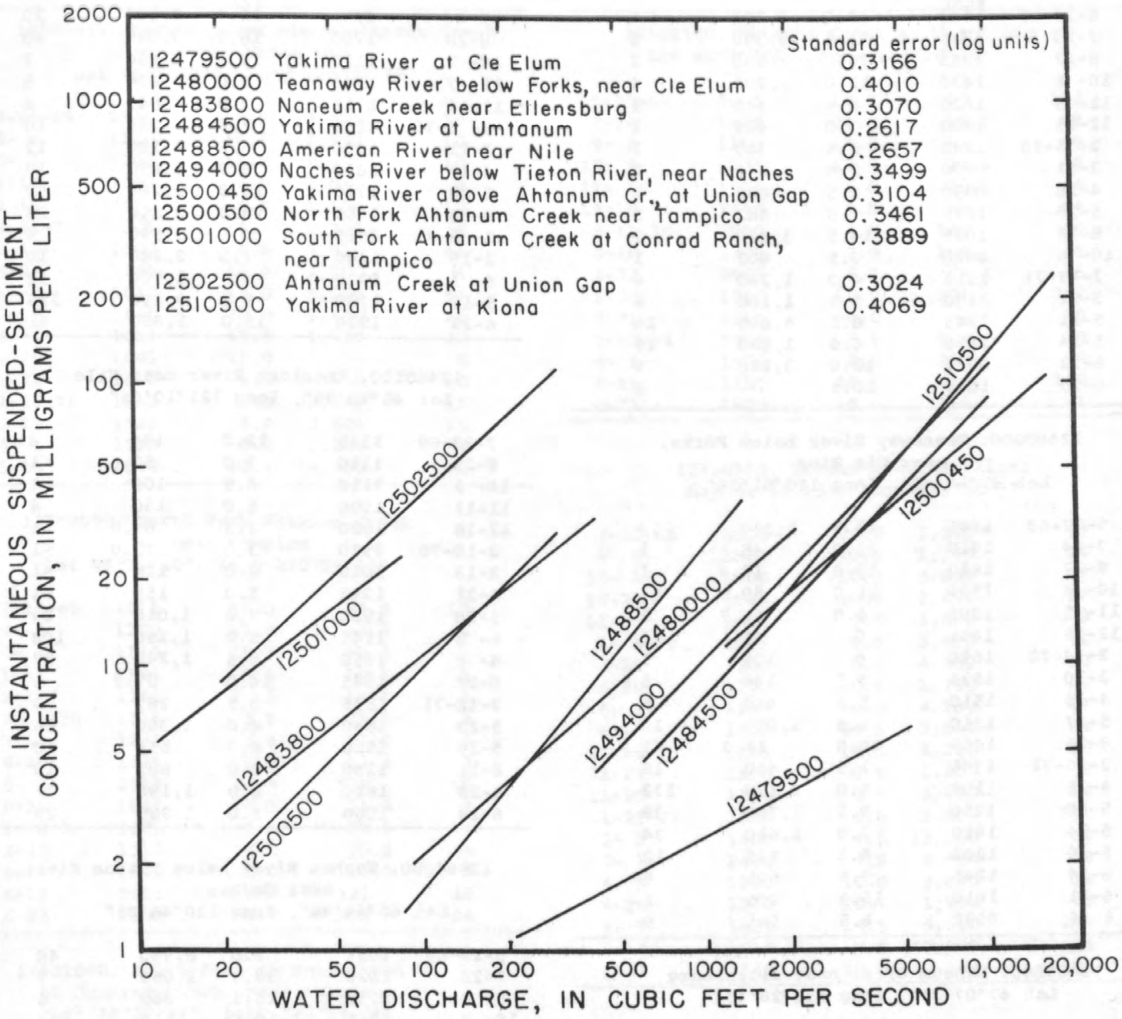

FIGURE 9.--Relation of suspended-sediment concentration to water discharge at 11 sites in the Yakima River basin.

TABLE 18.--Suspended-sediment concentrations at 11 periodic-sampling sites in the Yakima River basin. Sites are shown on plate 1 and listed in table 1

12479500. Yakima River at Cle Elum
Lat 47°11'33", long 120°56'48"

Date	Time (24 hr)	Water temperature (°C)	Discharge (cfs)	Suspended-sediment concentration (mg/l)
5-22-69	1520	12.0	3,200	8
7-23	1745	11.5	3,340	2
8-27	1355	15.0	2,830	2
10- 6	1430	12.0	1,200	4
11- 5	1020	6.5	148	1
12-15	1300	3.0	409	1
2- 5-70	1245	1.5	349	1
3-11	0900	2.0	343	2
4-16	0850	3.5	692	1
5-28	1015	7.0	582	5
8-26	1035	16.5	3,240	2
10- 6	0920	9.5	805	1
2-17-71	1115	4.0	1,260	4
3-31	1130	3.5	1,100	4
5-11	1945	8.5	5,090	10
5-14	1130	6.0	1,860	16
6-22	0835	12.0	3,160	5
6-25	1015	10.5	--	6

12480000. Teanaway River below Forks, near Cle Elum
Lat 47°14'48", long 120°51'36"

Date	Time (24 hr)	Water temperature (°C)	Discharge (cfs)	Suspended-sediment concentration (mg/l)
5-22-69	1445	13.5	1,320	16
7-24	1410	22.0	46	1
8-27	1610	17.0	13.9	1
10- 6	1525	11.0	59.8	<1
11- 5	1305	6.0	69.7	1
12-15	1455	0	51.1	<1
2- 4-70	1620	0	106	1
3-10	1525	3.5	178	6
4-15	1510	5.5	440	6
5-27	1310	9.5	1,090	10
8-26	1605	20.5	16.3	<1
2-16-71	1705	1.5	460	18
4-26	1100	6.0	1,170	172
5-10	1750	9.5	1,760	38
5-14	1410	7.0	1,610	34
5-20	1200	6.5	727	12
6-14	1245	9.5	671	6
6-21	1810	15.5	706	2
6-25	0935	8.5	561	9

12483800. Naneum Creek near Ellensburg
Lat 47°07'37", long 120°28'47"

Date	Time (24 hr)	Water temperature (°C)	Discharge (cfs)	Suspended-sediment concentration (mg/l)
7-24-69	1240	15.5	35.6	4
8-27	1245	9.5	19.2	2
10- 6	1115	6.5	16.4	2
11- 5	1700	5.0	22.6	4
12-16	1000	0	14.0	<1
2- 4-70	1255	.5	14.4	1
3-10	1235	.5	23.5	7
4-16	1615	5.5	37	3
5-27	1015	5.5	228	14
8-25	1720	16.0	17.4	2
2-17-71	1430	4.0	43	12
3-30	1650	4.5	31.5	24
5-10	1315	9.0	307	24
5-12	1055	6.5	354	45
6-23	1115	10.0	180	10

12484500. Yakima River at Umtanum
Lat 46°51'46", long 120°28'44"

Date	Time (24 hr)	Water temperature (°C)	Discharge (cfs)	Suspended-sediment concentration (mg/l)
7-24-69	0925	15.0	3,100	20
8-28	1700	16.5	3,090	10
10- 7	1110	10.5	1,660	7
11- 7	1145	8.0	474	5
12-16	1215	2.0	645	4
2- 6-70	1100	2.0	728	10
3-11	1300	6.0	1,180	12
4-17	1030	8.0	1,650	14
5-28	1700	13.0	2,280	58
8-26	1805	18.0	3,690	26
1- 6-71	0925	0	590	4
2-19	1140	3.5	2,280	10
4- 1	0920	4.5	1,900	12
5-12	1720	9.0	9,190	214
6-23	1520	15.0	5,850	41

12488500. American River near Nile
Lat 46°58'39", long 121°10'05"

Date	Time (24 hr)	Water temperature (°C)	Discharge (cfs)	Suspended-sediment concentration (mg/l)
7-23-69	1145	12.0	134	4
8-29	1110	7.0	52.6	<1
10- 2	1110	6.5	109	1
11-11	1900	6.0	130	4
12-16	1530	1.5	87.9	<1
2-10-70	0930	3.0	75.0	<1
3-13	1010	2.0	116	<1
4-21	1345	5.0	150	<1
5-18	1530	7.0	1,010	24
6- 3	1145	6.0	1,250	108
6- 8	1350	5.5	1,240	23
8-27	1545	14.0	57.2	1
2-18-71	1525	3.5	287	3
5-13	1630	4.0	1,360	66
5-19	1520	6.0	561	10
6-11	1130	6.0	882	10
6-22	1610	8.0	1,190	47
6-24	1050	5.0	1,230	29

12494000. Naches River below Tieton River, near Naches
Lat 46°44'44", long 120°46'05"

Date	Time (24 hr)	Water temperature (°C)	Discharge (cfs)	Suspended-sediment concentration (mg/l)
5-23-69	0855	8.0	6,950	48
7-23	1020	13.5	1,050	7
9- 4	0930	15.5	868	6
10- 2	1345	10.5	364	4
11- 6	1545	6.0	455	2
12-17	0930	1.0	106	1
2-10-70	1205	3.5	373	2
3-13	1215	4.5	364	5
4-21	1000	4.5	1,090	1
5-18	1400	10.0	3,680	37
6- 4	0910	8.5	6,660	264
6- 9	1030	9.0	4,230	39
8-27	1210	18.0	601	6
10- 7	1345	10.0	400	10
1- 7-71	1045	0	67.6	2
2-18	1130	3.5	1,540	6
4- 2	1040	4.0	286	3
5-13	1845	6.5	6,720	136
5-19	1720	9.0	3,330	20
5-20	0825	5.0	3,260	14
6-11	1330	11.0	3,570	15
6-24	1135	9.0	4,790	24
6-24	1655	10.0	4,500	37

TABLE 18.--Suspended-sediment concentrations at 11 periodic-sampling sites in the Yakima River basin. Sites are shown on plate 1 and listed in table 1--Continued

Date	Time (24 hr)	Water temper-ature (°C)	Dis-charge (cfs)	Suspended-sediment concentra-tion (mg/l)
12500450. Yakima River above Ahtanum Creek, at Union Gap Lat 46°32'04", long 120°27'58"				
7-25-69	1145	15.5	3,470	18
9- 4	1140	14.5	2,900	10
10- 7	1200	11.0	1,910	10
11-12	1600	8.0	1,030	8
12-18	1400	4.0	1,200	10
2-11-70	1205	4.5	1,790	38
3-18	1600	8.5	3,070	62
4-22	1135	10.0	2,200	6
6- 2	1030	12.0	6,090	57
8-28	1440	20.0	3,480	20
10- 9	1055	11.0	1,930	28
10-10	1045	11.0	--	8
11-22	1610	2.5	958	30
1-15-71	1515	1.0	1,540	15
2-19	1525	4.0	3,800	15
4- 1	1720	7.0	2,560	58
5-13	1540	11.5	14,400	148
12500500. North Fork Ahtanum Creek near Tampico Lat 46°33'40", long 120°55'10"				
7-22-69	1315	16.0	37.2	10
9- 3	1250	11.0	20.3	3
10- 3	1110	5.5	21.3	1
11-11	1105	3.5	19.5	1
12-17	1210	.5	19.5	1
2- 9-70	1315	3.5	25.6	2
3-12	1230	3.5	51.8	4
4-20	1435	5.0	63.3	2
6- 4	1715	13.5	328	58
8-28	1645	18.5	21.4	4
1- 8-71	1305	0	33.8	20
2-23	1310	2.0	75.2	4
4- 6	1030	6.0	83.9	8
5-11	0955	7.0	321	26
6-23	1135	9.0	273	24
12501000. South Fork Ahtanum Creek at Contrad Ranch, near Tampico Lat 46°30'33", long 120°54'36"				
7-22-69	1340	14.0	13.2	12
9- 3	1115	11.5	8.20	4
10- 3	1235	6.5	7.50	2
11-11	1015	4.5	7.05	<1
12-17	1415	1.0	6.49	1
2- 9-70	1135	3.0	10.3	2
3-12	1410	4.0	25.0	2
4-20	1230	5.0	20.0	2
6- 4	1915	12.0	67.0	34
8-28	1555	14.0	7.19	15
1- 8-71	1205	0	10.3	4
2-23	1430	3.0	20.8	3
4- 6	1235	7.0	33.6	14
5-11	1140	7.0	65	15
6-23	1355	9.0	67.0	22
12502500. Ahtanum Creek at Union Gap Lat 46°32'08", long 120°28'20"				
5-23-69	0805	10.5	50	104
7-24	1330	21.0	15.3	12
9- 2	1150	17.0	--	6
10- 2	1525	13.5	23.4	6
11- 7	1015	7.0	20.1	4
12-18	1540	5.5	35.4	14
2-11-70	0950	4.0	146	56
3-18	1305	7.0	164	46
4-22	0810	8.5	76.6	16
5-26	1950	10.0	271	242
8-31	1315	20.0	--	10
2-23-71	1720	5.5	124	28
4- 1	1700	8.0	164	50
5-11	1725	16.5	404	140
6-21	1820	19.0	266	81
12510500. Yakima River at Kiona Lat 46°15'13", long 119°28'27"				
7-30-69	0930	20.0	1,300	33
9- 9	1500	21.5	1,740	24
10- 17	1500	10.5	3,090	27
10-20	1315	10.0	2,490	27
11-25	1430	3.0	1,950	2
2- 3-70	1145	5.5	3,670	71
3-19	1200	9.0	4,390	58
4-28	1300	10.5	1,790	20
6- 1	1245	18.0	4,130	87
6-22	1050	24.5	2,640	64
10-15	1145	11.5	2,210	20
11-24	1150	3.5	1,800	3
11-30	1110	4.5	2,660	14
1-22-71	1025	1.0	7,800	221
2- 2	1405	4.5	12,800	286
3- 1	1430	4.5	4,390	58
4- 5	1200	11.0	3,630	58
4-28	1300	10.5	1,790	20
5- 7	1635	14.5	9,900	159
5-14	1410	7.0	15,000	34
6-21	1145	18.5	--	100

TABLE 19.--Suspended-sediment concentrations at 50 reconnaissance-sampling sites in the Yakima River basin. Sites are shown on plate 1 and are located only by latitude and longitude. Water discharge was estimated from measured cross-section geometry and surface velocity. Water discharges at sites denoted by number were measured using standard Geological Survey methods

Date	Time (24 hr)	Water temper-ature (°C)	Dis-charge (cfs)	Suspended-sediment concentra-tion (mg/l)
12474500. Yakima River near Martin Lat 47°19'17", long 121°20'06"				
7-23-69	1410	9.0	830	<1
11- 4	1400	5.5	--	2
8-26-70	1300	15.0	678	1
5-11-71	1320	4.5	669	2
12474700. Mosquito Creek near Easton Lat 47°17'32", long 121°19'23"				
11- 4-69	1450	5.0	4.37	71
12476000. Kachess River near Easton Lat 47°15'41", long 121°12'08"				
8-28-69	1035	15.5	--	1
11- 4	1250	8.0	--	1
6-22-71	1535	12.0	536	4
Big Creek near West Nelson Siding Lat 47°11'53", long 121°05'17"				
5-14-71	1405	--	300	25
Little Creek Lat 47°11'53", long 121°05'17"				
5-14-71	1410	--	100	116
Cle Elum River Lat 47°21'20", long 121°06'20"				
6- 9-70	1530	6.5	--	2
6-25-71	1050	6.0	2,500	6
12479000. Cle Elum River near Roslyn Lat 47°14'41", long 121°04'00"				
8-28-69	1350	14.5	--	1
11- 5	0920	6.5	2.26	<1
4-16-70	1325	4.5	440	1
5-11-71	0950	5.5	2,190	4
6-22	1835	13.5	2,780	3
West Fork Teanaway River Lat 47°15'31", long 120°54'13"				
6-10-70	0830	6.0	--	2
6- 1-71	1130	8.0	100	4
Middle Fork Teanaway River Lat 47°15'32", long 120°53'49"				
6-10-70	0805	5.5	200	2
6- 1-71	1135	7.0	200	2
North Fork Teanaway River Lat 47°15'18", long 120°52'40"				
6-10-70	0845	6.0	500	4
6- 1-71	1145	8.5	--	8
Swauk Creek Lat 47°19'34", long 120°40'18"				
5-19-70	1010	6.0	30	36
4-26-71	1140	6.0	--	35
First Creek Lat 47°12'30", long 120°41'53"				
4-26-71	1115	8.5	10	36
Swauk Creek Lat 47°12'01", long 120°42'28"				
5-19-70	0940	6.0	80	30
6-10	0910	6.0	30	13
4-26-71	1125	6.5	--	88
12483300. South Fork Manastash tributary near Ellensburg Lat 46°57'40", long 120°45'41"				
3-11-70	1145	1.0	3.00	2
Cherry Creek above Wilson Creek, near Thrall Lat 46°55'36", long 120°29'59"				
11- 6-69	1030	--	50	2,260
5-19-70	0845	10.5	80	162
Wilson Creek near Thrall Lat 46°55'35", long 120°30'02"				
11- 6-69	1005	6.0	57.1	24
12-16	1115	3.5	50	39
2- 6-70	0900	3.5	75	54
3-11	1215	6.5	75	52
4-17	0810	5.5	125	54
5-19	0830	10.0	200	154
5-28	1415	15.0	250	104
8-26	1710	19.5	200	25
10-10	1220	--	--	40
11-23	1310	4.5	--	66
1- 5-71	1645	1.0	--	20
1-20	1300	2.0	400	369
2-17	1730	6.5	--	60
3-26	0815	4.0	200	56
3-30	1820	8.0	174	58
5-12	1400	15.0	503	132
6-23	1400	17.0	--	56

TABLE 19.--Suspended-sediment concentrations at 50 reconnaissance-sampling sites in the Yakima River basin. Sites are shown on plate 1 and are located only by latitude and longitude. Water discharge was estimated from measured cross-section geometry and surface velocity. Water discharges at sites denoted by number were measured using standard Geological Survey methods--Continued

Date	Time (24 hr)	Water temper-ature (°C)	Dis-charge (cfs)	Suspended-sediment concentra-tion (mg/l)
Wenas Creek Lat 46°49'59", long 120°42'41"				
6- 9-70	1450	11.0	--	20
American River at Hells Crossing Lat 46°57'54", long 121°15'58"				
6- 8-70	1320	5.5	1,000	16
American River below Timber Creek Lat 46°54'54", long 121°23'07"				
6- 8-70	1250	5.5	700	2
12487400. Deep Creek near Goose Prairie Lat 46°47'30", long 121°19'30"				
11-11-69	1630	4.0	23.8	<1
Deep Creek Lat 46°49'59", long 121°18'36"				
6- 8-70	1445	5.0	800	7
12488000. Bumping River near Nile Lat 46°52'22", long 121°17'29"				
7-23-69	1430	13.5	213	2
8-28	1900	15.5	262	2
6- 3-70	1025	8.5	790	3
6- 8	1510	11.0	--	1
6-22-71	1335	11.0	965	3
Bumping River Lat 46°59'10", long 121°05'50"				
5-18-70	1510	9.0	--	15
5-19-71	1540	6.5	--	9
6-11	1155	8.0	3,000	6
6-24	1115	7.0	--	22
Little Naches River Lat 46°59'35", long 121°06'05"				
5-18-70	1600	8.0	--	20
6- 8	1540	6.5	1,300	17
5-19-71	1555	6.0	--	14
6-11	1115	6.0	1,000	4
6-24	1145	6.0	1,000	16
Milk Creek Lat 46°58'50", long 121°05'15"				
5-18-70	1615	9.5	--	449
6- 8	1550	10.5	10	195
5-19-71	1610	8.0	20	166
6-11	1205	8.5	20	477
6-24	1200	7.0	20	19

Date	Time (24 hr)	Water temper-ature (°C)	Dis-charge (cfs)	Suspended-sediment concentra-tion (mg/l)
Naches River at Cliffdell Lat 46°56'55", long 121°04'15"				
6- 8-70	1620	9.5	--	33
Nile Creek Lat 46°50'15", long 120°57'00"				
6- 8-70	1650	9.0	40	18
5-19-71	1630	8.5	30	20
6-11	1230	9.5	50	10
6-24	1225	8.0	20	12
Rattlesnake Creek Lat 46°49'15", long 120°56'05"				
5-18-70	1655	9.5	--	29
6- 8	1700	8.5	500	20
5-19-71	1640	8.0	350	20
6-11	1240	9.5	1,000	6
6-24	1235	7.0	300	18
Naches River Lat 46°44'45", long 120°47'15"				
6- 8-70	1730	10.5	--	68
5-19-71	1430	9.5	--	18
6-11	1340	10.0	--	10
6-24	1630	9.0	--	26
Short and Dirty Creek Lat 46°36'13", long 121°39'43"				
5-18-70	1330	8.5	--	84
6-11-71	0945	4.0	25	10
South Fork Tieton River Lat 46°36'47", long 121°10'18"				
5-18-70	1305	6.0	--	95
5-19-71	1310	5.5	700	22
6-11	1000	4.5	1,000	31
6-24	1445	7.0	1,500	64
North Fork Tieton River Lat 46°37'20", long 121°17'56"				
5-18-70	1105	4.5	--	18
6- 9	1150	5.5	1,500	18
5-19-71	1150	5.0	500	12
6-11	0915	5.0	500	4
6-24	1515	5.5	800	31
Clear Creek at Rimrock Lat 46°38'36", long 121°17'03"				
6- 9-70	1220	6.0	--	13
6-11-71	0900	5.5	100	7

TABLE 19.--Suspended-sediment concentrations at 50 reconnaissance-sampling sites in the Yakima River basin. Sites are shown on plate 1 and are located only by latitude and longitude. Water discharge was estimated from measured cross-section geometry and surface velocity. Water discharges at sites denoted by number were measured using standard Geological Survey methods--Continued

Date	Time (24 hr)	Water temper-ature (°C)	Dis-charge (cfs)	Suspended-sediment concentra-tion (mg/l)
Wildcat Creek Lat 46°39'55", long 121°07'25"				
6- 9-70	1240	6.5	50	10
12491700. Hause Creek near Rimrock Lat 46°40'33", long 121°04'49"				
11-10-69	1520	6.5	0.41	10
12492500. Tieton River at headworks of Tieton Canal, near Naches Lat 46°40'16", long 121°00'10"				
8-29-69	1450	15.5	560	5
11-10	1220	5.0	13.3	2
11-10	1345	7.0	5.73	6
4-21-70	1500	5.0	485	3
6- 3	1630	13.5	80	14
6-24-71	1025	10.0	930	18
Milk Creek near Rimrock Lat 46°40'07", long 121°05'08"				
5-19-71	1325	10.5	10	82
Tieton River at Windy Point Lat 46°41'45", long 120°55'				
5-19-71	1400	10.5	--	23
6-11	1410	15.5	200	8
6-24	1610	11.0	--	44
Oak Creek Lat 46°43'35", long 120°48'25"				
5-19-71	1415	9.0	30	16
Naches River near Selah Lat 46°37'50", long 120°35'10"				
6- 9-70	0945	10.5	--	32
Wapato Canal at Union Gap Lat 46°30'50", long 120°28'34"				
6- 9-70	0900	11.0	full	40
Ahtanum Creek near mouth Lat 46°33'00", long 120°31'25"				
5-23-69	0805	10.5	50	104
1-20-71	1135	2.0	300	190
Agency Creek Lat 46°22'10", long 120°46'25"				
4-20-70	1530	10.0	--	12
Toppenish Creek Lat 46°18'57", long 120°12'56"				
11-10-69	1020	8.0	54	42
12-19	1400	4.0	91	19
2-11-70	1400	4.0	344	79
2-16	1145	4.0	336	50
3-13	1520	8.0	367	22
4-17	1410	14.5	21	14
4-20	1610	9.0	51	46
6- 1	1520	20.0	218	52
6- 9	0830	12.0	--	51

(continued)

Date	Time (24 hr)	Water temper-ature (°C)	Dis-charge (cfs)	Suspended-sediment concentra-tion (mg/l)
Toppenish Creek--continued				
10-14-70	1120	--	437	23
11-24	1610	1.5	44	18
1-15-71	1120	.5	197	54
1-19	1340	3.5	543	200
1-20	0840	3.0	785	152
1-20	1000	3.0	796	110
2-22	1235	5.0	355	16
3-25	1445	8.5	--	47
4- 5	1535	13.5	501	28
5-10	1400	19.5	704	25
6-21	1455	20.0	136	46
Satus Creek at U.S. Highway 97 crossing Lat 46°14'08", long 120°25'04"				
1-19-71	1500	5.5	--	1,740
1-20	0915	3.0	800	612
3-25	1630	5.0	400	28
Dry Creek at U.S. Highway 97 crossing Lat 46°15'15", long 120°24'38"				
1-19-71	1430	5.5	600	2,430
1-20	0905	2.0	200	429
3-25	1650	5.0	--	18
Satus Irrigation Return Lat 46°16'25", long 120°08'43"				
4-20-70	1700	13.0	--	90
Satus Creek Lat 46°16'25", long 120°08'43"				
11- 7-69	1540	9.0	36	11
12-19	1330	5.0	49	19
2-11-70	1425	4.5	412	43
2-16	1130	3.5	1,450	764
3-13	1540	6.5	382	35
4-17	1430	14.0	164	46
4-20	1655	11.0	144	12
6- 1	1550	21.0	174	134
6- 9	0805	9.0	--	110
10-14	1140	--	107	14
11-24	1555	5.5	33	14
1-15-71	1050	1.0	--	28
1-19	1305	5.5	1,970	450
1-20	0820	2.0	2,120	466
2-22	1255	4.5	250	14
3-25	1430	5.5	--	89
4- 5	1550	10.5	400	82
5-10	1330	18.5	228	68
6-21	1515	20.0	142	59
South Drain Lat 46°15'35", long 120°07'57"				
1-19-71	1315	5.5	100	454
12505000. Yakima River near Parker Lat 46°29'47", long 120°26'24"				
9- 4-69	1520	15.5	280	.8
11- 7	1155	6.5	1,000	8

Small Streams Tributary to the Columbia River

Many small streams (independent of the subbasins delineated in fig. 2) flow into the Columbia River in the 410-mile reach between the international boundary near Northport and the river's confluence with the Yakima River at Richland (pl. 1); these small streams contribute relatively little sediment to the Coumbia River. The principal small streams in this reach are Big Sheep and Deep Creeks, which flow into the Columbia River upstream from Kettle River; Sherman, Hall, Wilmont, and Ninemile Creeks, which flow into the Columbia upstream from Spokane River; Hawk and Foster Creeks, which flow into the south side of the Columbia between the Okanogan and Spokane Rivers; and Moses Coulee, which is drained to the Columbia downstream from Rock Island Dam (pl. 1).

Precipitation along the Columbia River is greater near the Canadian border and generally decreases towards its confluence with the Yakima River at Richland (pl. 1).

The small tributary basins upstream from the Spokane River are mountainous, with peaks rising to 7,000 feet. The runoff is usually the result of snowmelt, although an occasional thunderstorm produces rapid runoff of short duration. The streams are generally clear and nearly free of sediment most of the time; the suspended-sediment concentrations measured at reconnaissance sites (table 20) during rapid runoff from snowmelt were less than 100 mg/l, except the 120 mg/l measured in Sherman Creek near Kettle Falls. Hawk Creek and other small tributaries downstream from Spokane River generally transport little sediment because (1) precipitation is light, (2) the soils absorb much of the precipitation, and (3) very little runoff occurs except during severe thunderstorms or during heavy rains falling on rapidly melting snow.

TABLE 20.--Suspended-sediment concentrations at 16 reconnaissance-sampling sites in small tributary streams along the Columbia River. Sites are shown on plate 1 and are located only by latitude and longitude. Water discharge was estimated from measured cross-section geometry and surface velocity

Date	Time (24 hr)	Water temper-ature (°C)	Dis-charge (cfs)	Suspended-sediment concentra-tion (mg/l)
Big Sheep Creek Lat 48°56'25", long 117°46'20"				
4-24-70	0910	5.5	--	4
Deep Creek near Northport Lat 48°55'32", long 117°44'50"				
4-24-70	0845	5.5	--	78
Onion Creek Lat 48°52'17", long 117°50'34"				
4-24-70	0810	5.5	--	48
Sherman Creek Lat 48°35'30", long 118°09'55"				
4-23-70	1600	7.0	--	14
4-29-71	1325	6.0	500	120
Barnaby Creek Lat 48°26'04", long 118°13'15"				
4-22-70	1745	9.5	--	26
Stranger Creek Lat 48°18'32", long 118°08'11"				
4-24-70	1045	8.0	--	17
Hall Creek near Inchelium Lat 48°18'23", long 118°12'30"				
4-22-70	1700	9.0	--	32
4-29-71	1230	6.5	700	126
South Fork Harvey Creek near Cedonia Lat 48°12'36", long 118°04'49"				
5-26-71	1355	13.0	--	340
Nez Perce Creek Lat 48°11'35", long 118°16'18"				
4-22-70	1430	8.5	--	44
Hunter Creek Lat 48°07'02", long 118°12'03"				
4-21-70	1610	10.0	--	18
Wilmont Creek Lat 48°04'34", long 118°19'29"				
4-22-70	1320	8.0	--	10
Ninemile Creek Lat 48°04'14", long 118°27'13"				
4-22-70	1025	7.0	--	34
Hawk Creek Lat 47°39'20", long 118°09'10"				
1-23-70	0915	1.0	--	10
2-16	1400	.5	349	228
Hawk Creek Lat 47°48'11", long 118°17'52"				
4-24-70	1235	11.5	--	8
East Foster Creek Lat 47°56'37", long 119°34'20"				
3-11-70	1545	5.0	10	13,200
West Foster Creek Lat 47°58'07", long 119°39'02"				
3-11-70	1615	7.0	20	1,030

The suspended-sediment concentrations generally are higher in the drier basins, even though very little or no runoff occurs in many of the small tributary channels during most years. During high and rapid runoff, large quantities of sediment are transported, such as that which occurred in Corbaley Canyon and Foster Creek in the northwestern part of the Columbia Plateau, probably during the high streamflows of 1948. The measured concentrations during 1970-71 ranged from 8 mg/l in Hawk Creek at Davenport to 13,200 mg/l in East Foster Creek. The high concentrations in East Foster Creek probably result chiefly from airborne sediment being deposited in snow and then transported as the snow melts. This type of sediment deposition and transport occurs in many places in the semiarid parts of the Columbia Basin. The estimated annual suspended-sediment yield is less than 25 tons per square mile for these small stream basins.

Columbia Plateau

The part of the Columbia Plateau included in this study (L in fig. 2) covers about 8,000 square miles east and south of the Columbia River in east-central Washington (pl. 1). The semiarid plateau has an undulating surface and is characterized by scablands and deeply cut coulees. The altitude of the area studied ranges from 3,051 feet on Hanning Butte on the northeast margin of the area to about 340 feet at Lake Wallula on the Columbia River near Pasco. The annual precipitation on the plateau is low, ranging from less than 10 inches near Pasco in the southern part to nearly 20 inches in the northern part (pl. 1). The runoff also is low, with short tributaries along the Columbia River generally flowing briefly during periods of snowmelt and (or) heavy rainfall. Crab Creek, with a drainage area of 4,864 square miles, is the principal stream in the area. During 1970 the mean discharge of Crab Creek to the Columbia River, measured at the gage near Beverly, was 210 cfs (U.S. Geological Survey, 1970).

The flow of Crab Creek varies along its length. Upstream from Stratford (pl. 1) the flow is intermittent and relies on runoff from snowmelt and occasional thunderstorms. Downstream from Stratford--and within the Columbia Basin Irrigation Project area--the stream flows continually as a result of seepage from project canals and irrigation return flow.

At the mouth of Crab Creek near Beverly, the discharge is increasing irrigation.

Sediment transported in the intermittent reaches of Crab Creek and its tributaries is deposited along the channels. The sediment carried by Crab Creek upstream from the town of Wilson Creek is deposited in the reach in the vicinity of the town where the high streamflow is ponded for long periods. The estimated annual suspended-sediment yield of Crab Creek near Irby is 60 tons per square mile. The yield of the Wilson Creek basin has not been estimated, but the few data gathered (table 21) indicate that it probably is greater than the 86 tons per square mile calculated by Hough and Flaxman (1936) from 19 years of sediment accumulation in the Bennett irrigation and silting basin. However, the accumulated sediment may not represent the total sediment transport to the silting basin because (1) during large floods the gates are opened or the dam may be topped, (2) water is spilled after the reservoir is filled, and (3) some sediment is deposited in control sections above the dam by the use of spreader dikes.

Suspended-sediment concentrations in streams on the Columbia Plateau range from less than 20 mg/l in many streams to 234,000 mg/l in Providence Coulee at Cunningham. A major part of the annual sediment discharge is transported similarly as in the Palouse River basin (Boucher, 1970, p. 31), when events occur as follows: (1) the soil is frozen at low temperatures, (2) snow falls on the frozen ground, and (3) rising temperatures, accompanied by rain, cause the snow to melt and the soil to thaw, with the top few inches becoming completely saturated with moisture. Thus, the rapid runoff resulting from rainfall and melting snow transports the saturated soil very easily and rapidly. However, because of large variations in (1) the amount of snow on the ground, (2) the rate of increase and magnitude of temperature, and (3) the rate of precipitation, the suspended-sediment concentration does not relate to streamflow.

During periods of rapid runoff the type and thickness of soil cover are important in governing the amount of material eroded and transported to the streams. The Columbia Plateau is composed largely of thin, rocky soils of the basalt scabland and deep loessal soil, as partially mapped by Bingham (Luzier and Burt, 1974). The quantity of sediment removed from areas of loessal soil is much more than that removed from scabland areas. Also, bare cultivated fields generally yield more sediment than do cultivated fields having a surface-layer mixture of grain stubble and soil. The suspended-sediment concentrations are much higher in the Esquatzel, Lind, Weber, and Rocky Coulee basins than in the upper Crab Creek basin which contains a larger proportion of scabland. Sediment concentrations during high streamflow are nearly 200,000 mg/l at times in Providence Coulee and generally less than 2,000 mg/l in the Crab Creek drainage.

The estimated yield of 600 tons per square mile of the Providence Coulee basin reflects a source of fine windblown sediments available for transport. Sediment yields probably are similar for many of the adjacent coulees. The sediment yields of Esquatzel Coulee decreases downstream owing to a flatter gradient, and to channel storage and a general decrease of runoff downstream. Analysis of the few data collected in the Esquatzel Coulee basin (table 19) suggests that the sediment yields there are greater than other parts of the upper Columbia River basin. Yields in the Esquatzel Coulee basin were estimated from little data, therefore additional data are needed to estimate the yields with the same confidence as that of the yields estimated elsewhere in the Columbia River basin. The suspended-sediment concentrations observed at periodic- and reconnaissance-sampling sites on streams on the Columbia Plateau during the study period are listed in tables 21 and 22, respectively. The relations of suspended-sediment concentration to water discharge are shown for six sites in the Crab Creek basin in figure 10 and for two sites in the Esquatzel Coulee basin in figure 11.

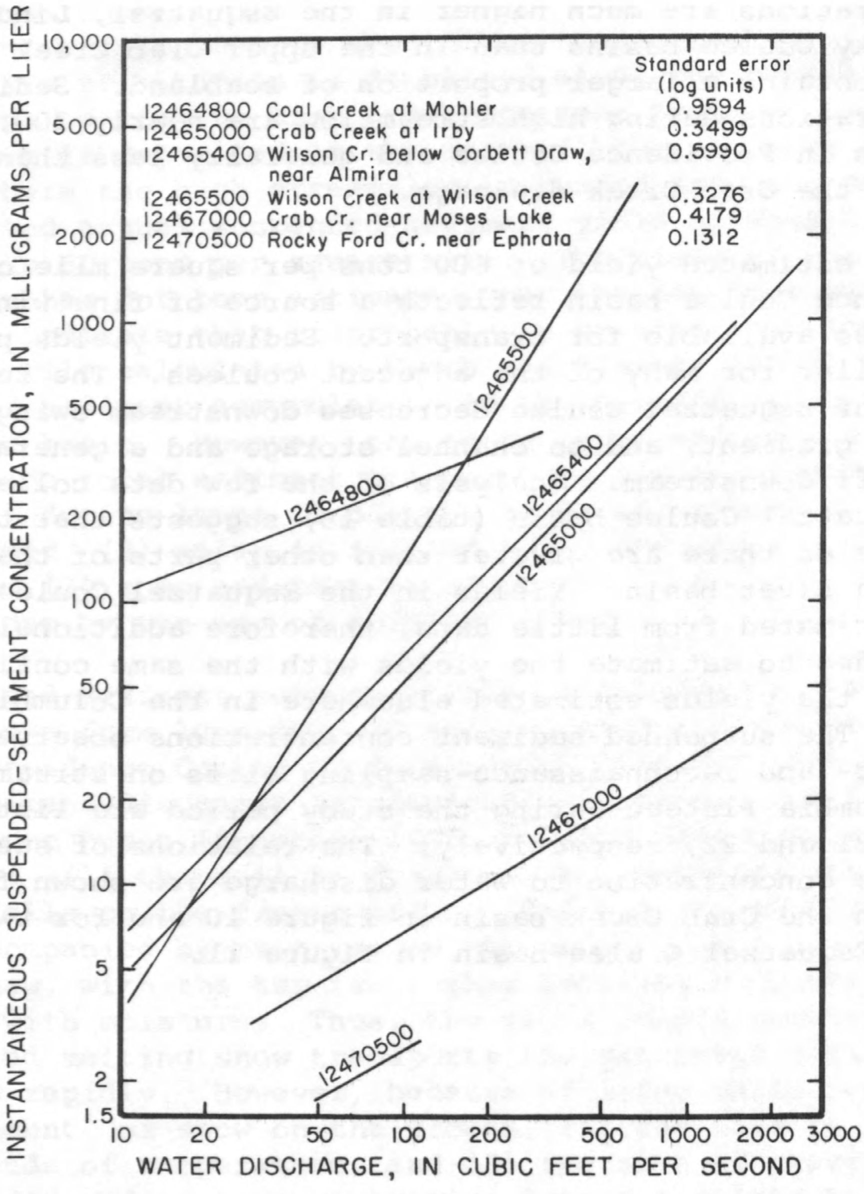

FIGURE 10.--Relation of suspended-sediment concentration to water discharge at six sites in the Crab Creek basin.

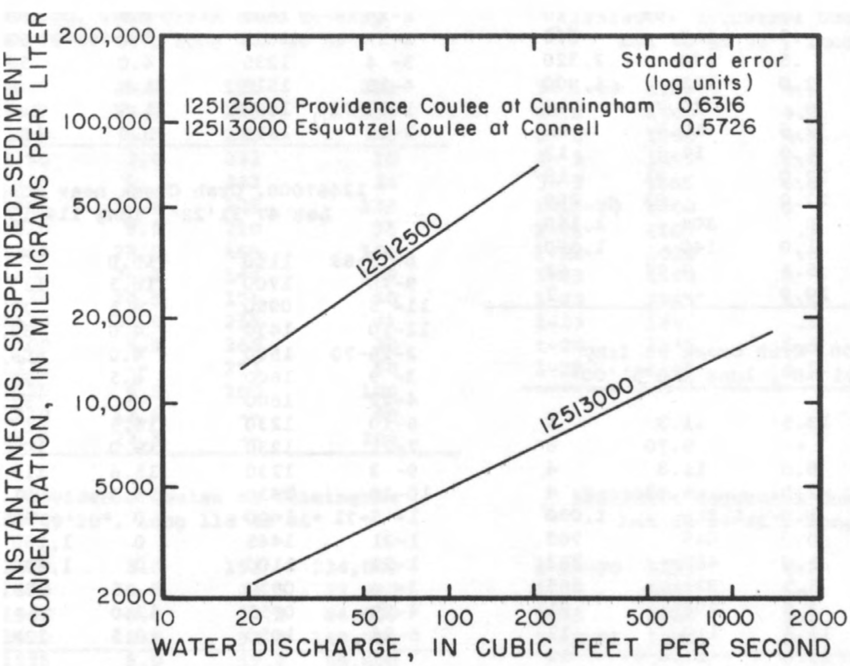

FIGURE 11.--Relation of suspended-sediment concentration to water discharge at two sites in the Esquatzel Coulee basin.

TABLE 21.--Suspended-sediment concentrations at 11 periodic-sampling sites on the Columbia Plateau. Sites are shown on plate 1 and listed in table 1

12464800. Coal Creek at Mohler
Lat 47°24'23", long 118°18'54"

Date	Time (24 hr)	Water temper-ature (°C)	Dis-charge (cfs)	Suspended-sediment concentra-tion (mg/l)
8- 4-69	1220	19.0	0.01	14
9-15	1300	14.0	.01	338
11- 3	0930	7.0	.02	2
12- 9	1100	.5	.22	2
1-19-70	1215	.5	.88	10
1-23	1115	.5	113	652
1-23	1520	.5	170	2,320
1-24	1900	2.0	122	1,900
1-28	1215	0	40.7	213
3- 4	1130	2.0	10.3	16
3-13	1130	6.0	12.3	13
5-25	1400	22.0	.81	18
7-28	1630	22.0	.03	208
1-17-71	1630	0	309	1,160
1-18	1500	1.0	140	1,690
2- 1	1200	5.5	9.72	62
4- 7	1515	10.0	--	7

12465000. Crab Creek at Irby
Lat 47°21'40", long 118°51'00"

Date	Time (24 hr)	Water temper-ature (°C)	Dis-charge (cfs)	Suspended-sediment concentra-tion (mg/l)
9- 4-69	1355	13.5	11.3	1
9-22	1300	--	9.70	6
11- 3	1500	8.0	11.3	4
12-16	1200	2.0	6.73	4
1-25-70	1205	1.0	1,210	1,050
1-26	0835	0	849	763
1-30	1600	1.0	468	263
2-19	1520	5.5	939	565
3- 4	1525	3.5	294	81
4-15	1720	11.5	110	11
5-18	1750	15.0	27.4	12
7-13	1615	19.5	22.0	15
8-28	1210	20.5	8.32	16
1-18-71	1000	0	2,550	2,010
1-20	1115	0	1,770	904
1-22	1530	2.0	438	530
3-19	0930	3.0	--	305
5-13	0940	14.5	29.9	26

12465400. Wilson Creek below Corbett Draw, near Almira
Lat 47°39'47", long 118°55'46"

Date	Time (24 hr)	Water temper-ature (°C)	Dis-charge (cfs)	Suspended-sediment concentra-tion (mg/l)
9-25-69	1650	15.5	1.47	8
11- 3	1130	9.0	2.56	2
12-17	1235	6.0	4.35	1
1-23-70	1240	0	172	188
2-16	1740	2.0	1,420	2,450
2-17	1200	2.0	850	616
2-25	1150	6.0	104	144
2-25	1230	6.0	103	644
3- 5	1040	4.0	47.9	31
4-13	1310	11.0	32.7	8
5-19	1640	18.5	11.8	10
7-13	1110	18.0	2.34	6
8-24	1305	20.0	.96	4
3-19-71	1215	3.0	--	301
3-25	1235	5.0	136	4,030

12465500. Wilson Creek at Wilson Creek
Lat 47°25'50", long 119°06'10"

Date	Time (24 hr)	Water temper-ature (°C)	Dis-charge (cfs)	Suspended-sediment concentra-tion (mg/l)
1-24-70	1115	0.5	369	1,490
1-25	1110	1.0	286	450
1-26	0915	0	103	146
2-17	1600	2.0	682	1,120
2-25	1505	8.5	88.9	140
2-27	1620	5.0	62.5	144
3- 4	1235	4.0	58.5	26
4-15	1515	11.5	8.99	2
1-19-71	1650	1.5	312	2,660
3-19	1315	9.0	106	311

12467000. Crab Creek near Moses Lake
Lat 47°11'22", long 119°15'53"

Date	Time (24 hr)	Water temper-ature (°C)	Dis-charge (cfs)	Suspended-sediment concentra-tion (mg/l)
8- 5-69	1150	15.0	100	22
9-16	1700	16.5	115	13
11- 5	0950	8.5	77.3	10
12-10	1430	4.0	34.9	24
2-26-70	1500	4.0	604	213
3- 9	1600	8.5	295	132
4-22	1600	--	97.4	41
6-10	1230	16.5	87.1	59
7-21	1230	19.0	106	43
9- 3	1230	15.6	119	54
10-29	1430	9.5	91.9	52
1- 5-71	1400	0	25.0	56
1-21	1445	0	1,150	212
1-22	1100	0	1,430	298
3- 4	0930	.5	36.6	66
4-29	0955	12.0	--	111
6-24	1050	8.5	120	4

124705000. Rocky Ford Creek near Ephrata
Lat 47°18'36", long 119°26'39"

Date	Time (24 hr)	Water temper-ature (°C)	Dis-charge (cfs)	Suspended-sediment concentra-tion (mg/l)
9-22-69	1600	13.5	107	4
11- 4	1115	11.5	98.6	2
12-16	1640	10.0	83.4	2
2-27-70	1430	9.5	67.7	3
5-18	1435	15.0	87.2	2
7-14	0900	14.5	99.6	2
8-27	0845	13.0	103	4
10-20	0900	12.0	94.2	2
12- 7	1240	11.5	83.6	2
3- 9-71	0845	11.0	70.8	2
5- 7	1130	13.0	--	1

12471270. Farrier Coulee near Schrag
Lat 47°07'33", long 118°50'17"

Date	Time (24 hr)	Water temper-ature (°C)	Dis-charge (cfs)	Suspended-sediment concentra-tion (mg/l)
1-23-70	--	--	232	16,100
1-24	--	--	63.6	10,800
1-25	0950	1.0	.05	1,570

TABLE 21.--Suspended-sediment concentrations at 11 periodic-sampling sites on the Columbia Plateau. Sites are shown on plate 1 and listed in table 1--Continued

12472600. Crab Creek near Beverly
Lat 46°49'48", long 119°49'48"

Date	Time (24 hr)	Water temperature (°C)	Discharge (cfs)	Suspended-sediment concentration (mg/l)
7-24-69	1020	25.0	111	202
9- 5	1445	17.0	180	114
10-15	1010	6.0	245	6
11-24	1350	3.0	232	10
1-12-70	1430	0	242	24
2-26	1405	10.0	238	124
4- 8	1020	9.0	210	75
5-21	1345	23.0	165	106
7- 2	1600	26.5	147	188
8-17	1430	20.5	171	90
10- 1	1630	17.0	255	41
11-30	1100	5.5	268	30
12-18	1330	--	253	60
3-16-71	1625	9.0	200	100
4-28	1210	12.0	--	88
6-21	1130	23.5	--	204

12512500. Providence Coulee at Cunningham
Lat 46°49'20", long 118°48'36"

Date	Time (24 hr)	Water temperature (°C)	Discharge (cfs)	Suspended-sediment concentration (mg/l)
2-27-69	1420	3.5	153	234,000
3- 1	1430	6.5	23.3	22,400
3- 1	1500	6.0	33.2	64,600
3- 1	1620	5.5	52.8	140,000
3- 2	1535	5.0	57.2	98,800
3- 3	1515	6.0	34.0	83,800
1-14-70	1700	0	73.6	6,560
1-15	1645	0	1.22	648
1-21	1255	0	118	2,200
1-22	1610	0	106	8,990
1-23	1155	.5	119	30,200
1-23	1325	2.0	142	56,400
1-24	1320	3.0	38.6	18,000
1-25	1505	4.0	6.71	19,100
11-25	1030	.5	.42	538

12513000. Esquatzel Coulee at Connell
Lat 46°39'31", long 118°52'03"

Date	Time (24 hr)	Water temperature (°C)	Discharge (cfs)	Suspended-sediment concentration (mg/l)
3- 1-69	1725	4.5	249	38,800
3- 2	1500	4.5	36	5,400
3- 3	1250	4.5	445	1,840
3- 3	1415	5.0	495	2,260
3- 3	1635	6.0	242	45,100
1-15-70	1200	0	18.8	1,150
1-21	1105	.5	67	850
1-22	1030	.5	85.7	1,070
1-22	2330	0	1,310	32,800
1-23	1245	1.5	845	18,400
1-23	1405	.5	686	14,500
1-24	1135	1.5	96.6	17,000
1-25	1205	3.5	12.1	3,740

12513500. Esquatzel Coulee at Eltopia
Lat 46°27'45", long 119°00'40"

Date	Time (24 hr)	Water temperature (°C)	Discharge (cfs)	Suspended-sediment concentration (mg/l)
1-23-70	2135	0.5	1,110	4,500
1-24	1000	--	395	3,380
1-25	1025	2.0	100	1,460
1-18-71	1035	2.0	35.5	5,170

TABLE 22.--Suspended-sediment concentrations at 21 reconnaissance-sampling sites on the Columbia Plateau. Sites are shown on plate 1 and are located only by latitude and longitude. Water discharge was estimated from measured cross-section geometry and surface velocity

Date	Time (24 hr)	Water temper-ature (°C)	Dis-charge (cfs)	Suspended-sediment concentra-tion (mg/l)
Crab Creek above Great Creek, at Canby Lat 47°30'20", long 118°02'10"				
1-26-71	1415	4.0	100	745
Great Creek at Canby Lat 47°29'50", long 118°01'10"				
1-26-71	1345	4.0	35	1,890
Crab Creek near Downs Lat 47°18'50", long 118°25'15"				
1-25-70	1330	1.5	--	910
1-28	1330	.5	--	534
Drain at Downs Lat 47°22'00", long 118°24'10"				
1-25-70	1350	2.0	10	2,680
Coal Creek at Lamona Lat 47°21'35", long 118°29'15"				
1-23-70	1330	0.5	200	3,550
1-18-71	1630	2.8	125	702
Coal Creek at mouth Lat 47°20'03", long 118°35'55"				
1-25-70	1450	2.0	100	974
Crab Creek at Odessa Lat 47°20'00", long 118°41'05"				
1-23-70	1615	0.5	--	1,800
1-24	0950	0	--	351
1-24	1035	.5	--	491
Lake Creek north of Odessa Lat 47°25'05", long 118°41'10"				
1-30-70	1415	5.0	15	83
Sullivan Creek above Outlet Creek Lat 47°27'55", long 118°46'00"				
2- 3-70	1250	1.0	--	<1
Goose Creek at U.S. Highway 2, at Wilbur Lat 47°45'29", long 118°41'58"				
2-16-70	1610	1.0	360	1,990
Rocky Coulee at Batum Lat 47°14'22", long 118°48'48"				
1-23-70	1500	1.0	700	11,800
1-23	1930	3.0	400	7,240
1-24	1030	0	55	15,000
1-24	1120	1.5	--	33,400
Rocky Coulee at Ruff Lat 47°10'59", long 118°59'16"				
1-25-70	1015	1.0	40	3,660
Bauer Coulee at Schrag Lat 47°04'18", long 118°50'23"				
1-23-70	1440	3.0	--	7,420
1-23	--	--	130	3,520
1-24	--	--	250	68,600
1-25	0930	1.0	30	4,960
Weber Coulee near Warden Lat 47°05'07", long 119°00'57"				
1-24-70	--	--	1,000	53,800
Lind Coulee at Lind Lat 46°13'15", long 118°37'00"				
1-22-70	1500	1.0	200	32,800
1-23	1400	2.0	200	4,840
1-25	0900	1.5	30	1,990
Lind Coulee tributary near Lind Lat 46°13'10", long 118°39'55"				
1-22-70	--	--	100	51,800
Lind Coulee tributary #2 near Lind Lat 47°13'10", long 118°39'30"				
1-22-70	--	--	45	36,600
Lind Coulee at State Highway 17 crossing Lat 47°00'40", long 119°08'15"				
1-24-70	1245	1.0	--	6,260
Drain into Potholes Canal at State Highway 17 crossing Lat 46°43'47", long 119°02'56"				
1-24-70	1345	1.0	--	598
Hatton Coulee Lat 46°45'20", long 118°49'55"				
1-23-70	1315	3.0	50	9,320
Unnamed Coulee Lat 46°42'30", long 118°50'15"				
1-23-70	1300	1.5	50	32,000

LITERATURE CITED

Boucher, P. R., 1970, Sediment transport by streams in the Palouse River basin, Washington and Idaho, July 1961-June 1965: U.S. Geol. Survey Water-Supply Paper 1899-C, 37 p.

Colby, B. R., 1956, Relationship of sediment discharge to streamflow: U.S. Geol. Survey open-file report, 170 p.

Fenneman, N. M , 1931, Physiography of Western United States: New York, McGraw-Hill Book Co., Inc., 534 p.

Hough, J. L., and Flaxman, E. M., 1936, Sedimentation survey of the Bennett irrigation and silting basin, Wilson Creek, Washington: Washington Agr. Experiment Station, Pullman, Washington.

Luzier, J. E., and Burt, R. J., 1974, Ground-water hydrology and irrigation development in east-central Washington: Washington Dept. Ecology Water-Supply Bull. 33 (in press).

Nelson, L. M., 1970, A method of estimating annual suspended-sediment discharge, in Geological Survey research 1970: U.S. Geol. Survey Prof. Paper 700-C, p. C233-C236.

-----1971, Sediment transport by streams in the Snohomish River basin, Washington, October 1967-June 1969: U.S. Geol. Survey open-file report, 44 p.

Pacific Northwest River Basins Commission, 1971, Land measures and watershed protection, appendix VIII, v. 2 of Columbia-North Pacific Region comprehensive framework study of water and related lands: Vancouver, Wash., 365 p.

Smith, L. H., Dwyer, C. H., Nunns, F. K., Schafer, G. M., Olsen, Harvey, and Klauss, D. W., 1958, Soil survey - Yakima County, Washington: U.S. Dept. Agr., Bur. Plant Indus., Soils and Agr. Eng., series 1942, no. 15, 143 p.

U.S. Geological Survey, 1970, Water resources data for Washington, part 1, Surface water records, 1970: Tacoma, Wash., Water Resources Division.

U.S. Inter-Agency Committee, Subcommittee on Sedimentation, 1940-63, A study of methods used in measurement and analysis of sediment loads in streams, repts. 1-14.

U.S. Weather Bureau, 1965, Mean annual precipitation, 1930-1957, State of Washington: Portland, Oreg., U.S. Soil Conserv. Service, map M-4430.